

FACULTY OF DENTISTRY LIBRARY
UNIVERSITY OF TORONTO



3 1761 03924687 1

UNIV. OF
TORONTO
LIBRARY



Digitized by the Internet Archive
in 2026 with funding from
University of Toronto

<https://archive.org/details/31761039246871>

Recd
C

Canadian Dental Research
Foundation

Bulletin: 15225 (1933-47)

Trismus Due to the Involvement of the Mandibular Nerve

BY

S. W. LESLIE, M.D., D.D.S.



A Thesis Awarded First Prize in Competition Held by the Canadian Dental Association
for Dental Research, 1932



415027
—
1.9.43

BULLETIN NUMBER FIFTEEN

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

1933 - 43

Trismus Due to the Involvement of the Mandibular Nerve

BY
S. W. LESLIE, M.D., D.D.S.



A Thesis Awarded First Prize in Competition Held by the Canadian Dental Association
for Dental Research, 1932



BULLETIN NUMBER FIFTEEN

ISSUED BY
THE CANADIAN DENTAL RESEARCH FOUNDATION
1933

OUTLINE

- (1) Purpose of Study.
- (2) Definition.
- (3) Etiology.
- (4) Anatomy.
- (5) Neuro-Muscular Physiology.
- (6) Pathology.
- (7) Symptoms.
- (8) Diagnosis.
- (9) Treatment—Prophylactic and Symptomatic.
- (10) Conclusions and Case Histories.
- (11) Bibliography.

PURPOSE OF STUDY

IN the course of operative work, the practitioner quite often meets with unforeseen complications, which may be followed by a very stormy and prolonged convalescence, after an apparently common operation such as a simple extraction. When this occurs it may appear to be, on superficial examination, a grave misfortune. It tends to upset the peace of mind of the operator as well as elicit extreme apprehension on the part of the patient. Still, the complication is not actually so serious, the gravity of the condition being greatly exaggerated by the doubt which may exist in the practitioner's mind as to his ability to handle the situation. This doubt originates because of the lack of knowledge of the etiology and treatment of this condition. This study was undertaken to ascertain the causes, the possible complications, the sequellae and the treatment. The discussion of the subject will be under the title of "Trismus," due to the involvement of the mandibular division of the trigeminal nerve, following the outline as above noted.

DEFINITION

"Trismus" is defined as a tetanic, muscular contraction of the muscles of the lower maxilla or mandible.

ETIOLOGY

In discussing the causative factors of Trismus, it is the intention of this article to prove that it is always due to involvement of the mandibular nerve.

We frequently observe a certain type of limited Trismus which may be due to actual injury to muscles and related structures during the extraction of a tooth. In this case the Trismus is usually caused by excessive trauma or careless exodontic procedures.

There may also exist a type of Trismus which is quite rare, and has been called Neurotic or Hysterical Trismus. The patients are usually of a nervous disposition, and complain of inability to open the mouth properly. In these cases

one should look for inflammatory conditions existing in the nose, throat, ear, and jaws. The related structures, such as the tongue, palate and salivary glands, should not be overlooked. When these areas have been found to be negative, then, and then only, should a diagnosis of Neurotic Trismus be made.

Reflexly, the following are the most frequent causes of Trismus:

- (a) *Caries* in teeth of the lower maxilla, usually in premolars and molars.
- (b) *Malposed*, partially erupted, or fully impacted lower wisdom teeth.
- (c) *Traumatic* injury to muscles and related structures, as in fractures of the lower jaw.
- (d) *Infective* and inflammatory processes existing in the lower jaws and related structures, such as alveolar abscesses of an acute or chronic nature, hypercementomata and residual roots, as well as radicular cysts.
- (e) *Pressure* by impacted teeth directly upon nerve fibres which are branches of the inferior alveolar nerve.

Here may be mentioned also, as a possible cause, the principle of contra pressure or "push" which is used before a tooth is extracted or "pulled."

Actual disease in the nerve tissue, which causes a sort of neuritis, may cause Trismus. We may consider, here, the Trismus of Tic Doloireux or Trigeminal Neuralgia, of which the actual cause is at present unknown.

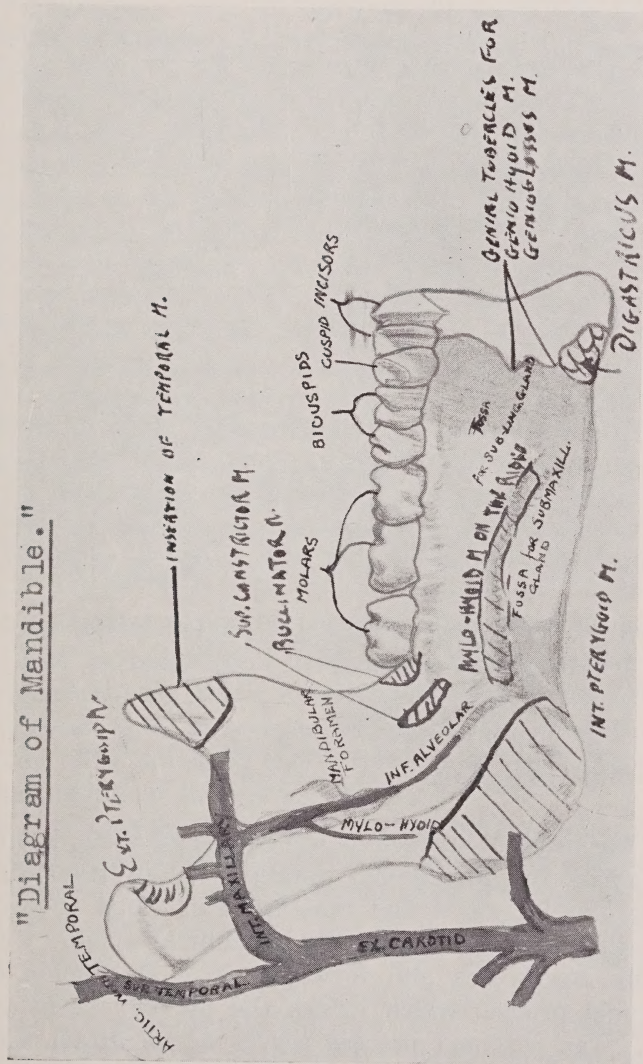
Various types of Stomatitis, such as Gangrenous and Ulcerative Stomatitis, may also cause a Trismus to develop.

APPLIED ANATOMY

Let us now discuss the anatomical parts which are affected by this spasmodic contraction, or "Trismus." We must consider the mandible, the tempro-mandibular articulation, the muscles of mastication, the muscles forming the floor of the mouth, and the trigeminal nerve in general, but paying particular attention to the mandibular division.

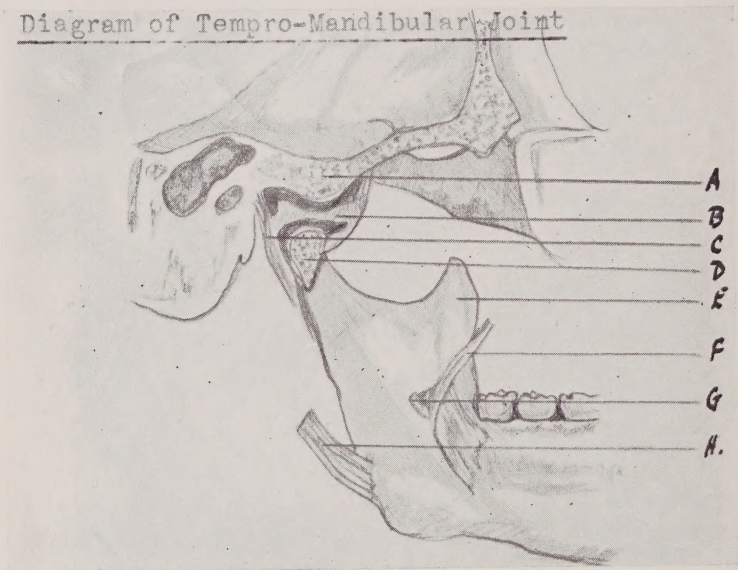
For the purposes of our subject we will cover only the anatomical features of each part mentioned above, inasmuch as they may be involved in the Trismus. For fuller and more detailed accounts, those interested may refer to standard texts on Anatomy.

The mandible is the largest bone of the face. It acts as



a support for the mandibular teeth. It also serves as the origin and the insertion of the muscles which are chiefly concerned in Trismus.

By means of a pair of condyles of the rami it articulates with the glenoid fossae of the temporal bones forming the tempro-mandibular articulation.



- A. EMINENTIA ARTICULARIS OF TEMPORAL BONE
- B. INTERARTICULAR FIBROCARILAGE
- C. CAPSULAR LIGAMENT.
- D. CONDYLE
- E. CORONOID PROCESS
- F. SPHENO-MANDIBULAR LIGAMENT
- G. MANDIBULAR CANAL AND SPINE
- H. STYLO-MANDIBULAR LIGAMENT

On the internal surface of the ramus at about the centre there exists the mandibular foramen which transmits the inferior alveolar nerve and vessels. This canal is protected from injury at this place by the mandibular spine. Running obliquely downwards and forwards from this spine is the mylo-hyoid groove, which lodges the mylo-hyoid nerve and artery. The coronoid process serves as an attachment for

the temporalis muscle, and also the masseter muscles on the external surface.

The tempro-mandibular articulation is, primarily, of the hinge-joint variety. Besides being able to open and close as a hinge does, we also have the ability to retract and protrude the lower jaw upon the upper. Some lateral movement is also attainable on each side because of the peculiar oval shape of the upper surface of the condyle.

Four ligaments aid in uniting the mandible with the temporal bone. They are, the capsular, the inter-articular fibro-cartilage, the stylo-mandibular, and the spheno mandibular ligaments. It is this last-named ligament which is so frequently damaged during the so-called mandibular injection to obtain block anaesthesia of the inferior alveolar nerve.

The nerve supply to the joint is derived from the masseteric and auriculo-temporal nerves as they run over the sigmoid notch of the mandible.

The muscles of mastication have their origin at the base of the skull and they are inserted into the lower jaw.

They are the internal and external pterygoids, and the temporal and masseter muscles. The internal pterygoid muscle arises from the pterygoid fossa and the tuberosity of the superior maxilla. It is inserted into the internal surface of the ramus of the mandible as far down as the mylo-hyoid ridge.

The external pterygoid has its origin in the pterygoid crest and the neighboring under-surface of the great wing of the sphenoid bone, while some muscle bundles also arise from the palatal bone and from the tuberosity of the superior maxilla. The muscle is inserted into a depression at the neck of the condyle of the lower jaw.

The temporals are very large, fan-shaped muscles which originate in the temporal crest and fossa of the temporal bone, and are inserted into the coronoid process of the mandible.

The masseter muscles arise from the lower border and inner surface of the zygomatic arch, and are inserted into the outer surface of the ramus of the mandible.

The above-mentioned muscles control the closing of the mouth, and also the protrusion and retraction of the mandible.

Lateral movements are chiefly controlled by the external pterygoids.

The opening of the mouth is controlled by the infrahyoid muscles. The weight of the lower jaw itself is a factor in this movement.

We thus note here that there are really only four muscles primarily concerned in Trismus, and the chief nerve supply of these muscles are branches of the trigeminal nerve.

However, we will mention later in our discussion of the Fifth Nerve, some of the muscles of the floor of the mouth, and of the palate, because they are very closely related to the muscles of mastication. Besides, their nerve supply is very intimately connected with the nerve branches of the mandibular division of the trigeminal.

The motor nerve fibres have their origin in the nucleus of the brain. These are collected into a root which lies beside the sensory root, as it makes its entrance into the brain tissue.

The motor root then passes upwards and forwards to the anterior fossae of the cranial cavity. Thence it proceeds to the mouth of Meckle's cave, where it lies below and lateral to the Gasserian ganglion, from the cells of which the sensory roots arise. At this juncture the Gasserian ganglion divides into the three divisions of the Fifth Nerve, namely, the ophthalmic, the maxillary, and the mandibular.

In this position the motor root continues its course to the foramen ovale, by means of which it makes its exit from the base of the skull. Immediately upon its emergence from the skull it unites with the sensory nerve root, and we now have formed the third division of the trigeminal or the mandibular nerve.

We can thus see that by the union of these two roots a very large nerve trunk is formed, and, in fact, the mandibular nerve is the largest division of the Fifth Cranial Nerve.

The mandibular trunk is now situated between the Pterygoideus externus muscle, externally, and the otic ganglion and the tensor palati muscle, internally. It now undergoes a division into anterior and posterior parts, both of which contain sensory and motor fibres. Before undergoing this

division, however, it gives off a small branch, the spinous nerve or the recurrent nerve to the dura of the brain. Although we are not at present concerned with this nerve, in passing one may note here the existence of a possible cause of headache, in some cases, due to the reflex stimuli from an aching or infected tooth.

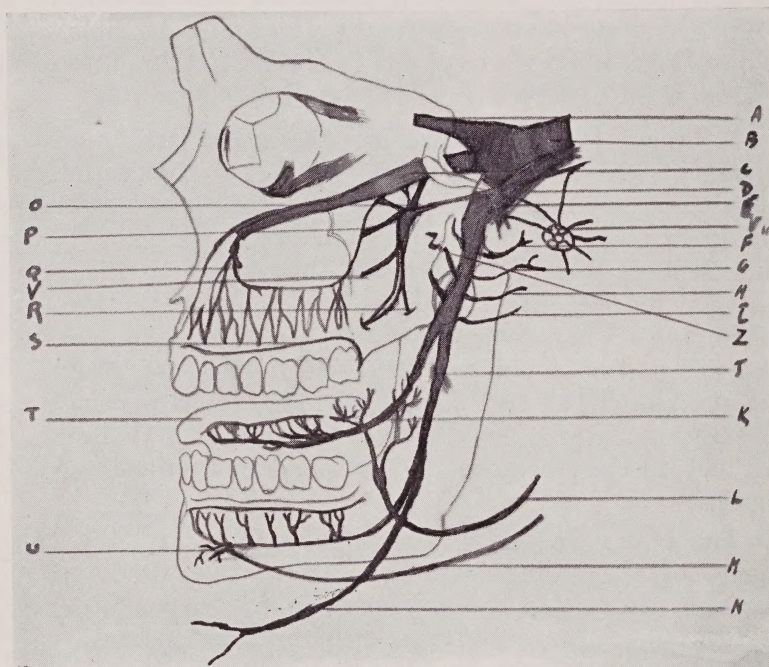
A branch to the Pterygoidus internus muscle is also, at this point, given off. The nerve to the Pterygoideus internus muscle not only acts as the motor nerve supply to that muscle, but gives off a motor branch to the otic ganglion. Through this medium small branches are distributed to the tensor tympani muscle, whose function it is to tense the tympanic membrane or eardrum. Here we see a possible cause for earache, and no doubt everyone who is in active practice of his profession has had some patients who have complained of earache, and who have received treatment for that ailment, without success, because the cause is some offending lower tooth.

The tensor veli palati muscles, which control the movements of the soft palate, also receive their nerve supply through the otic ganglion. Hence interference with speech is also quite often a sign presented by some patients.

The anterior portion of the mandibular nerve is the motor nerve for the muscles of mastication. The temporal muscles, whose function, as we have seen, is to close and retract the jaw, are supplied by the deep temporal branches. The masseteric nerve, which frequently arises along with the long buccal or the buccinator nerve. This latter nerve is the sensory part of this anterior portion, as it supplies the mucous membrane on the inner surface of the oral cavity as far forward as the angle of the mouth.

The posterior portion is also composed of motor and sensory fibres, but in this case the sensory fibres predominate. Two branches are exclusively sensory, namely, the lingual to the tongue, and the auriculo-temporal. The third branch, the inferior alveolar, with which we are chiefly concerned, is mainly sensory to the lower teeth and gums, but it also gives off the mylo-hyoid nerve, which acts as the motor nerve for

DIAGRAMMATIC REPRESENTATION OF THE FIFTH NERVE AND ITS BRANCHES



- A. OPHTHALMIC DIVISION
- B. GASSERIAN GANGLION
- C. MAXILLARY DIVISION
- D. MOTOR ROOT
- E. MANDIBULAR DIVISION
- F. OTIC GANGLION
- G. TEMPORAL NERVE
- H. MASSETER NERVE
- I. EXTERNAL PTERYGOID AND BUCCINATOR NERVE
- J. INTERNAL PTERYGOID NERVE
- K. AURICULO TEMPORAL NERVE TO JOINT AND TO AUDITORY MEATUS
- L. INFERIOR ALVEOLAR NERVE
- M. LINGUAL NERVE
- N. HYPOGLOSSAL NERVE
- O. MANDIBULAR BRANCH OF FACIAL NERVE
- P. MYLO-HYOID NERVE
- Q. SPHENO PALATINE GANGLION
- R. POSTERIOR DENTAL NERVE
- S. ANTERIOR DENTAL NERVE
- T. NASO-PALATINE NERVE
- U. POSTERIOR PALATINE NERVE
- V. ANTERIOR PALATINE NERVE
- W. TONGUE
- X. MENTAL NERVE

the mylo-hyoideus muscle and anterior belly of the digastricus muscle. The last-named muscles form the floor of the mouth.

Although the course and branches of the inferior alveolar nerve are well known to all, yet for the sake of completion in our study, it might be wise to consider it to some extent. The alveolar or the dental nerve, the largest branch of the mandibular division of the trigeminal, begins on the inner side of the external pterygoid muscle and descends to a little space between the mandible and the stylo-mandibular ligament. Here it receives a few filaments of the lingual nerve, and it then enters the mandible, at about the middle of the inner surface through the mandibular foramen. It is protected at this point from injury by the mandibular spine. Immediately below its entrance runs the mylo-hyoid nerve, which is lodged in the mylo-hyoid groove. We have already referred to the destination of this latter nerve.

In its course through the ramus and body of the mandible, the inferior dental nerve is accompanied by the inferior alveolar artery. This artery is quite large, and is the source of blood supply to the teeth and surrounding structures. Yet, because of the density of the bony structure of the lower jaw, interference with the blood supply often leads to rapid necrosis. Both the artery and the nerve are lodged in the mandibular canal all along their course, and hence toxic matter, absorbed into the blood stream, may, and probably does, permeate to the nervous tissue. In this way a Trigeminal Neuralgia may be caused.

As the nerve trunk passes forward it sends off small filaments to supply the peridental and dental tissues, and also gives off a sizeable branch, the mental nerve at the mental foramen. The inferior alveolar nerves of both sides anastomose at the centre of the mandible to form the incisive branches. We also note that an anastomosis exists between the mandibular division of the facial nerve and mental branches of the inferior alveolar nerve at the region of the lower bicuspids by means of the mental nerve.

Furthermore, because of the anastomotic branches of the cervical plexus with the cervical branch of the facial, we may trace the origin of a possible pain in the shoulder or even over the shoulder and chest, to an infected tooth.

NEURO-MUSCULAR PHYSIOLOGY

Irritation of the sensory nerves in regions far remote from the affected organ sometimes causes severe pain. In order to understand the mechanism and to interpret the significance of reflex or referred pain, it is not only necessary to know the nerve supply of the part, but also to what other organs the same or very closely related nerves are distributed.

"Impulses capable of producing autonomic pain in all probability arise in afferent autonomic nerve endings of the viscera. They pass along the afferent autonomic nerve fibres, which have their cell bodies, like the somatic afferent fibres, in the posterior (sensory) root ganglia."

"When the cells in these sensory ganglia are stimulated, pain arises. The cerebrum recognizes the pain and localizes its position. That site, however, is not the region where the pain stimulus originated, but in the peripheral distribution of the somatic sensory nerves, whose cells in the posterior root ganglia had been stimulated. This explains the term 'referred pain.'"

Let us now briefly consider the physiology of muscle and nerve tissue as it concerns us in Trismus. Muscle tissue acts as a supporting medium for the body. The primary function of muscle, however, is to contract and bring two bony points into apposition. The extent to which the muscle fibres contract depends, primarily, upon the strength and type of stimulus which is generated.

We cannot consider motor activity without understanding the conduction of nervous impulses by nerve fibres. There are three fundamental processes necessary to bring about this neuro-muscular action. We must have an exciting or initiating factor, which acts upon the so-called receptors of the sensory nerves. We have to deal with the conduction property of nerve fibres. And, lastly, the motor response of the muscle.

The excitability of a sensory nerve fibre rests, primarily, with the receptor organ. Although it must be remembered that the nerve fibres themselves retain the ability to become excited by the same stimuli which are received by the receptors.

The process of conduction of impulses is carried out by the nerve fibres, and this process is, in fact, the basic function of nerve tissue.

When the nerve fibre is stimulated, the conduction of the impulse is carried to the nerve cells of the motor-neurone by means of afferent fibres. At this juncture a synapse or intertwining takes place between the dendrites of the afferent nerve and the motor-neurone cell. The response to the stimulus is then carried to the muscle by means of efferent nerve fibres, which immediately initiate muscular activity. The process described above and illustrated below by the diagram is called the reflex arc.

It is the simplest and most primitive anatomical arrangement which brings about motor activity. We may mention here that impulses may travel or spread in either direction, along the axones of the nerve fibres. In the reflex arc, as illustrated above, the impulse travels only in one direction, because it must pass through the synapse. We thus see that the synapse offers resistance to the passage of nerve impulses. However, stimuli of increased intensity will cause the synapse to weaken, and excitation waves will spread to muscles in more distant parts of the body.

"If a series of weak stimuli are applied to the foot of a frog from which the brain has been removed, a flexion of the leg may be induced. If the stimulus is increased in strength, movements of the opposite leg will occur, while still stronger stimuli will cause the excitation to spread to the muscles of the trunk and forelimbs. This observation indicates that the impulses set up by a weak stimulus can pass only through those synapses which connect the afferent neurons with the motor neurons of the same limb, while stronger stimuli are required to set up impulses which can pass to the synapses leading to the motor paths to more remote muscles."

Let us illustrate the above quotation by the simplest reflex arc in the body, namely, the knee jerk. Thus, if we tap the patellar tendon gently, the resulting jerks are also weak; if, however, we increase the strength of the stimulus or tap, the result of response is increased in proportion. Reflex pain works in the same type of arc.

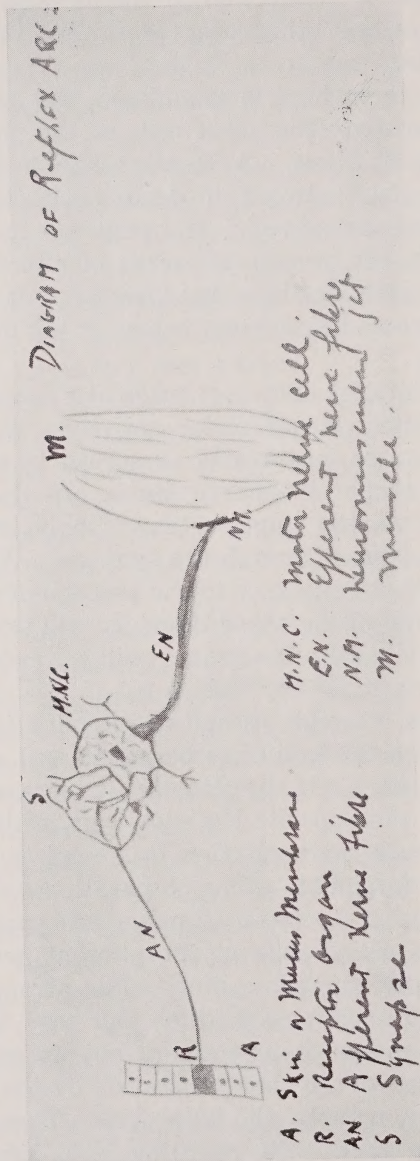
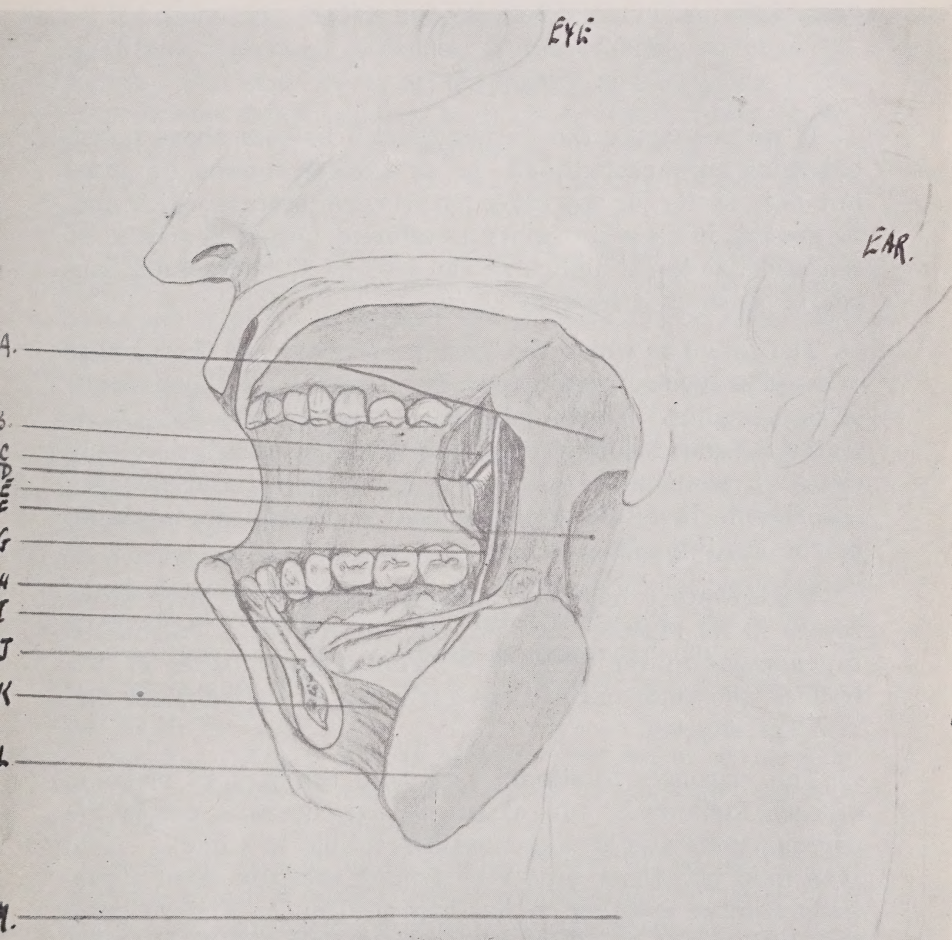


DIAGRAM TO ILLUSTRATE A REFLEX ARC

DIAGRAM TO ILLUSTRATE DIFFERENT AREAS, WHICH WHEN
DISEASED MAY AFFECT THE BRANCHES OF THE
TRIGEMINAL NERVE AND CAUSE TRISMUS



- A. HARD AND SOFT PALATES
- B. INFERIOR ALVEOLAR NERVE
- C. INFERIOR ALVEOLAR ARTERY
- D. BUCCAL TISSUE
- E. SPINE OF MANDIBLE
- F. FAUCES AND TONSIL
- G. LINGUAL NERVE
- H. GINGIVAL MUCOUS MEMBRANE
- I. SUBMAXILLARY SALIVARY GLAND
- J. CROSS-SECTION OF MANDIBLE
- K. GENIO-GLOSSUS AND DIGASTRICIS MUSCLE
- L. TONGUE
- M. LARYNX AND PHARYNX

PATHOLOGY

If we now apply the physiological principles above noted, but using an impacted tooth, or an alveolar abscess, or caries in a deep cavity, or any other pathological process which may be present in close proximity to afferent nerves or nerves of sensation, as the stimulus, we can see how the actual mechanism of Trismus is brought about.

The extent to which the Trismus develops and the number of muscles involved again depends, primarily, on the strength of the stimulus. Thus a pulp which has been absorbing toxic material from carious dentine for a lengthy period may only cause a Trismus after sufficient of the toxic material has been absorbed to break down the resistance of synapse, in acting as the excitation factor.

On the other hand, an inflammatory process may be so severe in its reaction that not only do we get a Trismus of the muscles in the immediate vicinity, but muscles of the back of the neck and even as far down as the shoulder and arm are affected.

The responses to stimuli vary with the nervous make-up of each individual. In hypersensitive, neurotic people the nervous system is always more susceptible to stimuli. Here even mild infections, or a very trifling pressure from a partially erupted tooth, or, as has happened in the writer's practice, in the case of a young neurotic female, the small quantity of toxic material absorbed from the gingival tissue around a poorly fitting crown, is enough to cause Trismus.

The pathology of Trismus can probably be best illustrated by appendicitis. In this condition we get a rigidity of the abdominal muscles. This is really due to the fact that, although the appendix is infected, the stimuli are so intense that muscles enervated by the same nerves as the appendix become affected and contract.

SYMPTOMS

The symptoms of Trismus vary with the cause. The most important symptom, of course, is the *inability to open the mouth*. This may be of a mild nature and last only a few days, or even a few minutes, as in the case of Trismus caused by attacks of Trigeminal Neuralgia, to as long as four to six weeks. The duration is usually directly related to the cause and to the type of tissue involved.

Pain as a symptom is not always present. When, however, the patient complains of pain in the lower jaw, it may be accompanied by an earache, which is, of course, only reflex pain.

Swelling may be present. If the Trismus follows an extraction of a lower posterior tooth, there may also be some interference with swallowing and a complaint of sore throat. A marked lymphatic adenitis on the affected side may occur after the extraction of an acutely infected tooth. Where no exodontia has been resorted to, and Trismus is present, the lymphadenitis may be due to a tonsillitis or peritonsillar abscess, or to an alveolar abscess. There may be a rise in temperature from one to three degrees, and one should be on the lookout for a possible periostitis and osteomyelitis setting in.

The patient may also complain of headache, constipation and general malaise, which may be due to the actual systemic upset caused by the complications.

Nervousness and apprehension because of the inability to open the mouth is quite a major symptom, the failure to open the mouth being quite frequently exaggerated.

There may also be evidence of fracture and traumatic injury of the lower jaw. Usually the affected muscles are quite hard and rigid on palpation on the affected side.

Blood findings usually show a moderate leucocytosis, particularly where some inflammatory or infective process is the cause. Albumin is frequently found in the urine.

DIAGNOSIS

Where Trismus develops after an extraction of a lower tooth, the diagnosis is simplified, and one should be on guard for a possible osteomyelitis.

The greatest fear on the part of the patient is, of course, tetanus, or so-called lockjaw. You may set the patient's mind at rest on this point if it is a post-extraction Trismus. Tetanus is caused by the introduction of foreign matter from the outside into deep closed wounds. In tetanus, muscle spasm is bilateral and the muscles of the back of the neck are involved.

Trigeminal Neuralgia can be ruled out from the history. The onset is sudden and the pain very severe. The attacks of pain usually originate in the same spot each time. The first and second branches of the trigeminal nerve are chiefly affected, but where Trismus is present, the third or mandibular branch may be involved.

Caries of the lower teeth can be confirmed by radiograph, from the history, and actual inspection. True ankylosis of the tempro-mandibular joint can be differentiated by the fact that no lateral movement is obtainable and from the history. The affected side is also flattened out, because of muscular atrophy of disuse.

Fractures, residual infections, cysts of types which may involve the nervous tissue, and impacted teeth can all be confirmed by radiographic examination.

Where no other cause is found a neuritis may be suspected. In these cases a hyperesthesia along the course of the affected nerve will act as a clue.

Some cerebral disturbances, such as bulbar paralysis, or encephalitis lethargica, etc., may cause a muscular spasm of the muscles of mastication. In these cases, of course, the history and other symptoms act as a guide. Care must always be taken not to overlook new growths or tumours of any type, situated in the jaw bones or on the mucous membranes, as well as the tongue and salivary glands.

Mumps can be differentiated by the swelling in front and behind the ear, the age of the patient, the history, and from a dental standpoint, the lack of any involvement of the teeth.

A possible mastoiditis may be the cause of Trismus. In this case the diagnosis is substantiated by pain on pressure over the mastoid process and the history of a running ear.

Ludwig's Angina or diffuse submaxillary cellulitis is characterized by ulcers and abscesses around the tongue. The hardening of the muscles of the floor of the mouth is usually bilateral. Extension into the throat, causing difficulty in breathing, is common.

Actinomycosis is commonly diagnosed by the history and occupation of the patient and presence of characteristic granules in the discharge.

TREATMENT

In this study the treatment is confined only to Trismus as caused by some dental conditions, and from the general practitioner's viewpoint.

It is said that the best treatment for any disease is to prevent its occurrence. This principle can also be applied here in many ways.

In the first place, too many extractions and operative dentistry procedures are carried on without the aid of radiographs. The X-ray would reveal to us the extent of caries in the crown of a tooth and aid in the proper filling. We can also visualize the possible extent of an inflammatory process at the apex of a tooth and the proximity of this infected area to the mandibular canal. Pulp involvement by deep-seated fillings, as well as pulp stones, could also be seen. Many other conditions, as illustrated by the case histories, are shown up by the radiograph, and thus aid in the treatment.

Where Trismus is just beginning, that is, the patient complains of a beginning inability to open the mouth, or where Trismus already exists, the extraction of the offending tooth is advisable.

When fully impacted or partially erupted teeth are found to be the cause, good judgment must be exercised before arriving at a decision to extract the tooth. Particularly is this true when there is evidence of an acute condition existing.

If swelling is present, with definite fluctuation, the pus should be evacuated as soon as possible, and the swelling allowed to recede before an attempt is made to remove the offending teeth. Should the decision be to remove the teeth at once, then allowance must be made for drainage, otherwise we may have many serious complications, not the least of them being an increased Trismus. If, however, after 48 hours the Trismus is not relieved, then the application of heat is best.

Where a lymphadenitis exists, dry heat applied is very good treatment. The infra-red rays from a lamp have been found to be of great value at this time.

Drainage of the affected area is imperative, as has already been mentioned, and where possible, daily syringing of the socket with warm normal saline solution or a very mild potassium permanganate solution is advisable. Packing the socket with sterile gauze is good also. Small sterilized rubber strips make good drainage facilitators.

For the pain, hypnotics such as luminal are advisable, and during the day, aspirin tablets or other analgesic drugs may be used.

The following prescription has been found quite efficacious in my work:

℞
 Codeia Phos. Gr. $\frac{1}{4}$
 Pyramidon Gr. 111
 Aspirini Gr. 11
 Misce fiat pulvis et pone in capsule, mitte tales VI
 Sig.: capiat unam q.3.H.

The administration of laxatives and the use of hot foot baths helps to raise the patient's general resistance.

Feeding is a problem in some cases. In the most severe cases, a rubber tube can even be inserted by means of the space where the tooth has been removed, and a liquid nourish-

ing diet prescribed. Where the tooth has not been removed and all the teeth are present, the tube can almost always be slipped into the mouth posterior to the teeth at the retro-molar triangle space. It is not necessary to remove a perfectly good tooth to accomplish the passage of a tube for purposes of feeding.

The separation of the jaws by means of mouth gags and springs is only necessary where the Trismus has existed for a long period of time, and true ankylosis of the temporomandibular articulation is feared. A general anaesthetic is necessary for this procedure.

Lastly, and probably the most important, is the psychic treatment of the patient. One should endeavor to soothe the fears of the patient by instilling in him confidence in your ability to handle the case. Where the nervous element is uppermost, bromides may be prescribed about one half-hour before the operation. Post-operatively, bromides can also be used.

A good prognosis, which can be given in almost all cases, also eases the mind of the patient and helps to attain a rapid recovery.

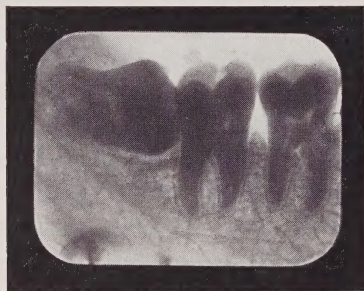
CONCLUSIONS

The various causes of Trismus have been dealt with, and it has been proven that Trismus is primarily reflex in origin. The neuro-muscular mechanism and the anatomical features of Trismus have been considered. An outline of the symptoms and treatment has also been set forth.

There is still much room for organized research into oral surgery problems. The composition of pulp stones and their possible relationship to such conditions as Tic Doloireux and Migrane should be investigated.

CASE HISTORIES

The accompanying case histories and radiographs have been chosen from the writer's practice to demonstrate the typical cases which may be met with in a dental practice.



CASE 1.

Mr. E. C. R.—Age 38; noticed loss of weight, complained of headaches, malaise, and increasing inability to open the mouth, for the past few years. Physician's diagnosis: migraine.

Radiograph reveals the condition which existed. Patient had uneventful recovery after removal of the tooth. Headaches disappeared and no Trismus resulted.



CASE 2.

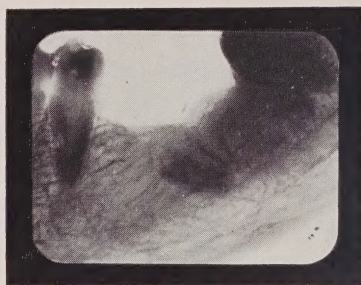
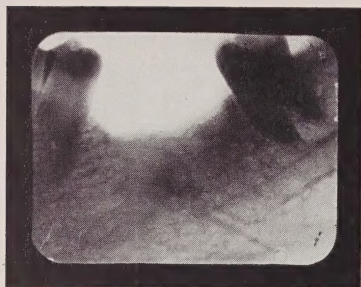
Mrs. S. S.—Age 22; has been losing weight for past two years, complained of loss of appetite and inability to chew her food well enough, because she does not seem to get any lateral movement of her lower jaw.

Radiograph revealed a dentigerous cyst. The removal was followed by a complete Trismus for a few days, which cleared up with treatment.



CASE 3.

Mr. B.—Age 38; was referred because of swelling, tenderness, and partial Trismus on the left side of face. The dentist had removed a few lower teeth. No radiographs were taken by him. Radiograph above illustrates a large radicular cyst which was the original cause of swelling and Trismus. Curiously, after the removal of the cyst, the patient reported a disappearance of hoarseness which had developed a number of years previously. This was probably due to reflex stimulation to the superior laryngeal nerve.



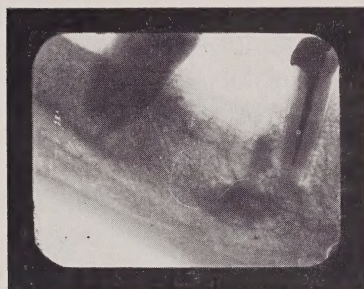
CASE 4.

Mr. H. D.—Age 38; had noticed that for a few weeks now he had been unable to open his mouth as well as he was used to. The removal of second molar after an X-ray was taken resulted in the aggravation of his complaint. The radiographs above show a cementoma (proven after section and microscopic examination) which gave prompt relief of his symptoms; a severe Trismus which lasted for ten days resulted after its removal.



CASE 5.

Mrs. V.—Age 43; complained of severe facial pain for a number of years and spasms of Trismus. Her surgeon diagnosed the condition as Tic Doreux, and referred her for injection of the mandibular nerve. Radiographs were just made, however, and they revealed a small residual area of the right lower second bicuspid. The removal of this area failed to give relief, and it was decided to remove the molar, *which had a large pulp stone in it*. Six weeks following the removal of the molar, the patient reported relief from all symptoms.



CASE 6.

Mr. S.—Was complaining of a conjunctivitis, and his oculist referred him to have his teeth examined. Radiographic examination, among other things, revealed a residual root with a large area of condensing osteitis on the left side. Following its removal, as well as the first bicuspid, a severe Trismus resulted, accompanied by a conjunctivitis in the left eye. Both conditions cleared up with treatments for the Trismus.



CASE 7.

Mr. B.—Complained of pain at the labial angle of the

mouth, which now and again resulted in a temporary inability to open the mouth. Radiograph revealed a small denticle under the lower left bicuspid, and lower teeth removed because of a systemic ailment. He reported relief from his pains in the jaws, but not complete relief of his systemic complaint.



CASE 8.

Miss M.—Age 19; very nervous individual; presented herself with pain, swelling on the lower right side, and Trismus. Said she couldn't open her mouth to full extent "for years," dentist said her wisdom teeth were coming out. Radiograph revealed two devitalized teeth with periapical involvement. Treatment was first instituted to relieve the pain and swelling, the teeth were later removed, with relief of symptoms.

The other radiograph is that of her sister, who also thought she was developing "lock-jaw."

Deep caries was discovered as above noted in radiograph. Some periapical involvement is also evident. Needless to say, the tooth was removed.



CASE 9.

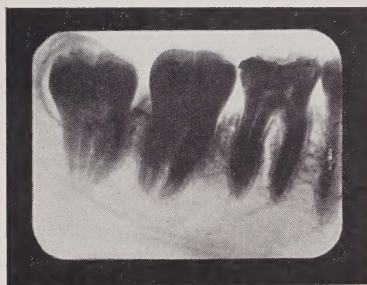
Mrs. M.—Age 39; presented with severe pain, temperature

102°, swelling, earache on the left side, a lymphadenitis in the neck on the affected side, and Trismus. Following the removal of a lower molar, a periostitis was suspected. After lengthy treatment, with only relief of swelling and Trismus, the radiograph was taken. Patient was hospitalized, and under a general anaesthetic the whole area was cleaned out. In a few days patient had relief from her earaches, which were most distressing, and a clearing up of other symptoms followed later.



CASE 10.

Mr. G.—A railway fireman; complained of shooting pains in the lower right side of face, which he could only relieve by closing his jaw tight. Thought he was catching colds because of exposure to heat and cold alternately. Had extractions done a number of years ago. Radiographs reveal how residual areas of infection can bring about the symptoms complained of.



CASE 11.

Mrs. F.—Age 29; very nervous type. Following the removal of the third molar, while demonstrating to a number of dentists, a very stormy convalescence resulted. Patient

had Trismus of the muscles of mastication and muscles of the neck, and pains down as far as her fingers in her left arm. Two weeks of treatment cleared up all symptoms, except for pains in the upper jaw. Radiograph reveals the condition previous to operation.



CASE 12.

Mrs. S.—Age 18; referred by her dentist following a simple extraction of a lower bicuspid. At that time there was a mild epidemic of infantile paralysis in the city, and patient was afraid she had developed it because of her Trismus, following the extraction. A possible fracture was also feared by her dentist, following the extraction.

Radiograph reveals the condition as being a Trismus due to infection extending directly into the mental foramen. Reassurance and hot fomentations cured patient in a few days. This case may also be used to illustrate Trismus, due to hysteria.

BIBLIOGRAPHY

McLeod, J. J. R.—Physiology and Biochemistry, Part 9, p. 832 and p. 842.

Davis, G. G.—Applied Anatomy, p. 45 to 131.

Morris—Textbook on Anatomy.

Gray—Textbook on Anatomy.

Blair and Ivy—Oral Surgery, Chapter 24.

Choyce—A System of Surgery.

Sir Watson Cheyene—"The Defensive Arrangements of the Body." Wightman lecture, 1908.

Brown, G. V.—Oral Diseases and Malformations, p. 145 and 146, p. 187, p. 405 to 430.

Burchard and Inglis—Dental Pathology and Therapeutics, Chapter 8.

Zinsser—Diseases of the Mouth.

Gaskell—The Involuntary Nervous System, p. 17.

Hubert—The Laryngoscope, 1923, 33, 596.

FOOTNOTE

A special dissection of the head and neck for the purpose of this study was carried out by the writer at the Anatomy Dept. of the University of Toronto.

The Canadian Dental Research Foundation

is the official Research Organization of the Dental Profession in the Dominion of Canada, two Directors being appointed by the Dental Board of each Province, and two Directors appointed, ex-officio, by virtue of their office in the Canadian Dental Association.

All subscriptions are forwarded by the Secretary to the National Trust Company, Trustees, the interest only being used in support of research work in the several Dental Colleges of Canada.

This Bulletin is the Fifteenth of a series of Bulletins to be issued by the Foundation. Complimentary copies of all Bulletins issued will be sent to Canadian Dental Practitioners.

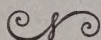
Any Dentist in Canada who feels that he has any original work worthy of publication is requested to forward it to the Foundation.

Copies of this Bulletin may be obtained from the Secretary, Canadian Dental Research Foundation, Room 312, Medical Arts Bldg., 86 Bloor St. W., Toronto, Canada.

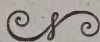
Bulletins Published by the Foundation:

- No. 1.—The Evolution of the Pus Pocket, May, 1921, H. K. Box. (31 Pages, 27 Illustrations.)
- No. 2.—The Rupert Hall Method for Entire Upper and Lower Dentures, July, 1921, W. E. Cummer. (50 Pages, 38 Illustrations.)
- Nos. 3 and 4.—The Dentinal Cemental Junction; Histological and Histo-Pathological Studies of the Dental Pulp, May, 1922, H. K. Box. (60 Pages, 82 Illustrations.)
- No. 5.—The Science and Practice of Partial Denture Service, with Special Reference to a Graphic Method of Design, May, 1922, W. E. Cummer. (27 Pages, 16 Illustrations.)
- No. 6.—Combinations as an Aid in the Discovery of Fundamentals in Dentistry, and Other Sciences, May, 1923, W. E. Cummer, G. R. Anderson, Robert J. Reade. (71 Pages, 120 Illustrations.)
- No. 7.—Studies in Periodontal Pathology; The Mechanics of Occlusion, Summary of the Signs of Incipient Periodontal Disease (issued in conjunction with the Department of Health, Province of Ontario), May, 1924, H. K. Box, G. R. Anderson. (120 Pages, 135 Illustrations.)
- No. 8.—Articulation for Partial Dentures with the Snow Apparatus and Wadsworth Incisor Guide, June, 1924, W. E. Cummer, I. H. Ante, J. A. Bothwell. (45 Pages, 39 Illustrations.)
- No. 9.—Combinations which Occur Between the Upper and Lower Six Posterior Natural Teeth in Occlusion, June, 1924, W. E. Cummer, R. G. Anderson, R. J. Reade. (18 Pages, 13 Illustrations, including folded Chart.)
- No. 10.—Treatment of the Periodontal Pocket (issued in conjunction with the Faculty of Dentistry, University of Toronto), September, 1928, H. K. Box. (124 Pages, 120 Illustrations.)
- No. 11.—Impressions in Partial Denture Service (presented at the Ontario and Canadian Dental Associations, 1926, and reprinted, with additions, from "Dental Cosmos," September, 1926; December, 1927; January, 1928; March, 1928; and January, 1929), October, 1929, W. E. Cummer, R. J. Reade. (70 Pages, 76 Illustrations.)
- No. 12.—Special Cavity Preparations and Casting Processes for Gold Inlays, Including Some of the Physical Phenomena Taking Place in the Materials Used, and Methods of Compensating for the Shrinkage of Gold, January, 1929, H. E. Bulvea.
- No. 13.—Ultra-Violet Rays, Their Application in the Practice of Dentistry, 1929, Robert J. Reade.
- No. 14.—Necrotic Gingivitis (Trench Mouth), 1930, Harold Keith Box.
- No. 15.—Trismus Due to the Involvement of the Mandibular Nerve, 1933, S. W. Leslie.
- No. 16.—A Process for Production of Copper Amalgam from Ingredients in Aqueous Solution, 1933, F. C. Husband.
- No. 17.—The Problem of Fac-simile Reproduction of Anterior Esthetics in Full Denture Prosthesis, 1933, Frank M. Lott.
- No. 18.—Periapical Tissue Changes in Teeth of Dogs, Following Various Methods of Pulp Removal and the Use of Various Common Drugs, 1933, G. A. Buchanan.

A Process for Production of Copper Amalgam from Ingredients in Aqueous Solution



BY
F. C. HUSBAND, D.D.S., L.D.S.
Toronto, Canada



BULLETIN NUMBER SIXTEEN

ISSUED BY
THE CANADIAN DENTAL RESEARCH FOUNDATION
July, 1933

A Process for Production of Copper Amalgam from Ingredients in Aqueous Solution



BY

F. C. HUSBAND, D.D.S., L.D.S.

Toronto, Canada



BULLETIN NUMBER SIXTEEN

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1933

A PROCESS FOR THE PRODUCTION OF COPPER AMALGAM FROM INGREDIENTS IN AQUEOUS SOLUTION¹

F. C. HUSBAND, D.D.S., L.D.S.

Toronto, Canada

I. INTRODUCTION

Twelve years ago, as the culmination of a series of tests by the Dental Research Committee of the University of Toronto under the supervision of the late Dr. J. J. MacKenzie, then head of the Pathological Department of the University of Toronto, attention was called to certain unique properties of copper amalgam. The tests had been made to determine the antiseptic values of various filling materials. Briefly stated, it was found that, of the materials having antiseptic property, *all but one* lost it after being transferred from one to three times, at intervals of two weeks, to fresh culture-media. The exception was copper amalgam, which continued to exhibit this property for five years—the period of the test.² In 1890, Miller, testing old copper-amalgam fillings which had been in mouths for many years, found them germicidal, and observed that the adjacent dentine exhibited germicidal properties also.³ This suggested to the writer the value of copper amalgam filling for the apical third of root canals. For twelve years it has been thus used by him, to the exclusion of all other materials, with gratifying results. Articles and papers, by the writer, have appeared from time to time in dental literature fully describing the characteristics of the material; the canal preparation and the technique of insertion; also the results, over a period of years, as checked with radiographs.⁴

¹ Read at the Tenth General Meeting of the International Association for Dental Research, Columbus, O., March 19-20, 1932.

² One of the preliminary reports was read at the Third General Meeting of the International Association for Dental Research. Chicago, Ill., March 20, 1925: *Journal of Dental Research*, 1928, viii, p. 220.

³ Miller: The micro-organisms of the human mouth; 1890.

⁴ Husband: *Dominion Dental Journal*, 1925, pp. 37 (Feb.) and 145 (May); 1926, p. 386 (Dec.). *Journal of the American Dental Association*, 1928, p. 248 (Feb.). *Journal of Dental Research*, 1928, viii, p. 220 (Apr.).

In all root-canal surgery, thorough opening of the canal is regarded as essential. Owing to the anatomical formations, this is often impossible; and teeth, where this condition has obtained, have been promptly consigned to the forceps. For some time the writer has been seeking means whereby copper amalgam could be obtained from ingredients in aqueous solution. It was felt that if one could start with an aqueous solution, greater penetration of the dentine could be obtained, and small tortuous canals could be followed by a fluid to the apex. It was also believed that although the spaces might not be completely filled or obliterated mechanically, a deposit of copper amalgam obtained in this manner would render the dentine effectively germicidal, as in the case of the dentine long in contact with the copper-amalgam fillings mentioned by Miller. The process for producing copper amalgam from aqueous solutions, as given below, is suggested for the treatment of very tortuous and inaccessible canals, lateral canals, apical foramina, and the adjacent tooth-tissue (dentine). The process would not take the place of ordinary copper amalgam, well inserted in thoroughly opened and prepared canals, but should be used as a supplement thereto. It enables the operator to deal effectively with what have heretofore been very difficult, if not impossible, situations.

II. CHEMICAL NATURE OF THE PROCESS

The three materials used in the process are copper sulphate (CuSO_4), hypophosphorus acid (H_3PO_2), and mercuric chloride (HgCl_2). When a solution of CuSO_4 or of HgCl_2 is mentioned, the saturated solution is meant. *Chemistry involved:* (a) when a solution of CuSO_4 in a test tube, (b) is treated with a few drops of H_3PO_2 , which is a powerful reducing agent, a yellowish precipitate that turns brown appears in about ten minutes. The precipitate is copper hydride (CuH or Cu_2H_2). (c) When to this mixture a solution of HgCl_2 is added, there results a heavy gray product, which is copper amalgam in a finely divided state. Copper throws mercury out of mercury-salt solutions. Thus copper wire, suspended in a mercury-salt solution, soon becomes coated with mercury. Reverting to item (b) above, it will be noted that CuSO_4 may be reduced to CuH . The latter can be

reduced to copper by heating to 60°C . This, while a simple procedure in a test tube, would be impossible in a root canal. It was found, however, that CuH is as effective as copper in throwing mercury out of mercury-salt solutions, the copper of CuH uniting with mercury from the mercury-salt solution to form copper amalgam. So far as the writer knows, *text books on chemistry do not record this reaction*. Two tests of the precipitated copper amalgam, obtained by filtration, were made for both copper and mercury, as follows: (a) A portion, held in the open flame of a bunsen burner, gave the characteristic green color for copper. (b) From a portion heated in a test tube, mercury globules were deposited on the sides of the tube.

III. APPLICATION TO ROOT THERAPY

This chemical procedure can be duplicated in root canals. In lower teeth, the liquids may be applied with college pliers or a dropper; gravitation will assist. In upper teeth, a wick of dry cotton lightly packed into the opened portion of the canal may be saturated, using college pliers alone to carry the liquids, or a loose pledget of cotton. Saturation of the tooth tissue will be assisted by capillary attraction. The treated parts must be saturated with the first of the solutions (CuSO_4), since the second and third stages involve precipitations, which take place only where the first solution is available. Further penetration does not occur to any great extent after precipitation. To apply quantities sufficient to insure saturation, two or three dressings may be required in actual practice. Each time the dressing must be sealed in with a good cement; temporary stopping or temporary cements are inadequate.⁵ The reduction of CuSO_4 to CuH requires ten minutes in a test tube, but much more time in a root canal. Therefore, after removing the surplus CuSO_4 , a liberal dressing of H_3PO_2 should be applied, and sealed in for at least twenty-four hours. The surplus may then be removed and HgCl_2 solution liberally applied, and allowed to act for at least twenty-four hours. This surplus may then be removed, thus completing the

⁵ Excesses of the applied liquids may irritate the periapical tissues, but this effect is only temporary. The results of unpublished work in relation to this matter indicate that no harmful effects ensue.

treatment for the production of copper amalgam in the inaccessible parts of the canals. The filling of the accessible portions should then be conducted as outlined in previous articles.⁴

IV. OTHER APPLICATIONS OF THIS PRINCIPLE

1. *Treatment of a fragment of a steel-broach in a canal.* Steel or iron throws copper out of copper-salt solution. For example, steel wire in copper sulphate solution is coated with copper in a few moments. Copper wire dipped in a mercury-salt solution is

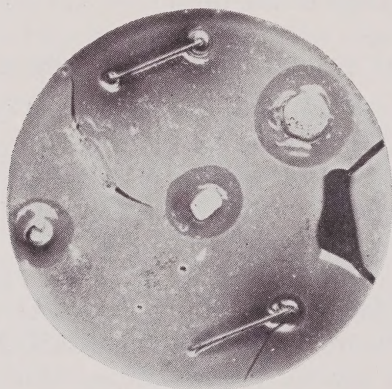


FIG. 1. Steel broaches, coated with copper amalgam, in infected agar.

Note areas of germicidal action around them. Pellet of ordinary copper amalgam at lower left; pellet of precipitated copper-amalgam, zinc oxide, and rosin at upper right.

coated with mercury. Steel wire, thus coated with copper, may be further coated with mercury when inserted in a mercury-salt solution; in other words, it is finally coated with copper amalgam. This takes place when a steel broach broken off in a canal, and difficult to remove, is there subjected to the process described above. The treatment with CuSO_4 followed by HgCl_2 coats the broach with copper amalgam, and thus makes it a potent germicide (*fig. 1*).

2. *Copper-amalgam root-canal points.* Copper wire does not show germicidal qualities when planted in infected agar. But

when coated by immersion in HgCl_2 solution, copper wire exerts marked germicidal power (*fig. 2*). Root-canal points, made of copper wire coated in this way, might have a useful place in the management of root canals of certain pulpless teeth.

3. *Treatment of deciduous teeth.* Precipitated copper-amalgam has been used by the writer in the treatment of pulpless deciduous teeth, with seemingly satisfactory results. Under these conditions, the roots appear to be stained jade green.

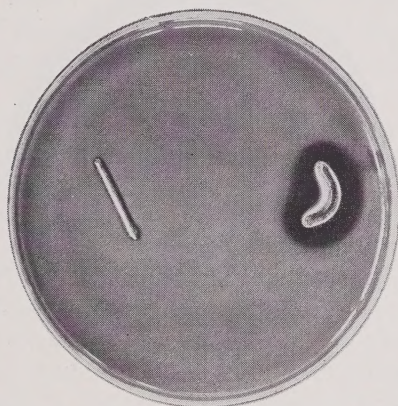


FIG. 2. Straight rod of plain copper, and curved rod of same kind (dipped in HgCl_2 solution and then thoroughly washed with water) in infected agar.

Straight rod has no germicidal property. Note germicidal power of curved rod coated with amalgam.

V. LABORATORY TESTS OF PENETRATION

Freshly extracted teeth were treated as follows: the pulp chambers were opened and cleared of debris; the canals were not opened or entered with instruments. The treatment was applied *only in the pulp chamber*. In a period of one to four days, *penetration of the dentine of the roots took place from the agents placed in the pulp chamber*. Some of the teeth were sectioned; others, after the crown cavity had been closed with oxyphosphate-of-zinc cement, and after having been thoroughly rinsed with water to remove any readily soluble material, were placed in petri

dishes containing staphylococcus-infected agar. In all cases, the dentine, for variable distances from the canal to the apex, excepting certain areas of dense calcification, was stained jade green. Those in infected agar showed marked germicidal power about the apical ends of the roots (*fig. 3*).

Steel broaches, coated with copper amalgam by the procedure described above, when placed in infected agar, showed germicidal



FIG. 3. Freshly extracted teeth treated, in pulp chamber only, by copper-amalgam precipitation process, and placed in staphylococcus-infected agar.

Marked germicidal effect shown at root apices.

properties (*fig. 1*). A plain copper-rod in infected agar showed no germicidal properties. But another copper-rod of the same kind, coated with amalgam by immersion in HgCl_2 solution and thoroughly rinsed with water, when placed in the same agar with the plain copper-rod, showed marked germicidal properties (*fig. 2*).

Staining of the tooth tissue, by this process or by the insertion of ordinary copper amalgam, is inevitable. But, by careful technique, the staining may be confined to parts of the root that are not visible.

COPPER AMALGAM AS A ROOT FILLING MATERIAL*

By F. C. HUSBAND, D.D.S., Toronto, Canada

THE antiseptic properties of copper amalgam have been known and experimentally attested to again and again for many decades. Miller made experiments to determine the antiseptic properties, if any, of filling materials. He not only found that copper amalgam, freshly prepared and old fillings, had antiseptic properties, but he also found what was more significant, that dentin from extracted teeth which had been filled with copper amalgam was not only sterile but had antiseptic properties also. Simms repeated the experiments of Miller, and found that copper amalgam and oxychlorid of zinc had definite antiseptic properties for some distance about them. Black says:

This amalgam has so many good qualities that many abandon it with much regret. I think it is generally acknowledged that copper amalgam fillings retain good margins, when they are once made perfect, better or more perfectly than any other filling material. Within the limits of its strength, it is as rigid as hardened steel. It does not contract, but exhibits very slight expansion on setting.

Black believed that its inhibition of caries was largely due to its perfect fitting of the cavity walls. Kirk says: "Its preservative qualities render it a valuable constituent in teeth of low grade structure." Foster Flagg says: "I regard copper as a most valuable constituent of any amalgam." Weagent says that copper amalgam acts as a preservative of the dentin by permeating the tubules with an antiseptic solution. Fraser¹ repeated the experiments of Miller, Simms, Black, Kirk and others and found that copper amalgam had antiseptic properties of a permanent character, and further that it retained its antiseptic properties after being transferred to a fresh medium every two weeks for a period of five years. Because of this permanent antiseptic property and the fact that clinical experience over many years had shown that it had no irritating properties in contact with vital tissues, it was suggested that "it might be used with decided advantage where discoloration

*Read before the Section on Anatomy, Physiology, Materia Medica and Therapeutics at the Seventh International Dental Congress, Philadelphia, Pa., Aug. 26. 1926

¹Fraser, C. Jane: *Dominion Dent. J.*, 37: 1 (Jan.) 1925

of the tooth is not a factor, as a temporary filling, or in root canals, in cavities below the gum line and when it could be covered on the exposed surface by another filling material."¹

Dr. Fitch² suggested the use of silver amalgam as a root canal filling in preference to gold foil or cotton wool, which were in common use. He evidently wished to be cautious in the matter, because he says "The writer does not wish to be understood as recommending it for this purpose, but would suggest some points of comparison."

It is quite apparent, from dental literature, that filling root canals with either silver or copper amalgam never became a general practice, since no text-book mentions it as a method to be followed. Copper amalgam was abandoned as a filling material chiefly because of its discoloration. As Black says, "Copper amalgam has many desirable properties which should not be lost sight of," and if the technique suggested below is followed, its undesirable property—discoloration—can be overcome, and its desirable properties utilized to preserve and save many otherwise doomed teeth and prevent infected areas about the tooth root end.

TECHNIC OF ROOT CANAL FILLING

The canal is prepared as for the Coolidge sectional method. Reasonable enlargement of the canal is necessary with choke bore or shoulder at the apical end. This shoulder preparation, as has been pointed out in connection with the Coolidge method for guttapercha, enables the operator to place the first section of the filling more definitely. Reamers in the engine should be used with the greatest care, if at all. Hand reamers are much safer.

A radiogram of the root with a diagnostic wire in place should first be made to determine exactly the length of the canal.

As large a root canal plugger as will pass to the end of the canal without binding should be chosen. The end of this plugger is dressed off with a cuttle fish disk in the engine so that it is flat and at right angles to the shaft of the plugger.

A shoulder is bent on the plugger so that the shoulder will rest on a given or chosen edge of the cavity margin when the point of the plugger is at the end of the canal.

²Fitch: American System of Dentistry, 1887

This shoulder indicates that the plugger is reaching to the end of the canal and no farther.

The copper is mixed quite smooth by adding or expressing mercury as required. The mix must not be "sloppy."

A small piece is carried to the mouth of the canal with pliers or an amalgam carrier, and gently guided into the mouth of the canal with a suitable plugger or small pledget of cotton in pliers, any suggestion of packing being avoided. A plugger, already selected with a shoulder as above described, is held with a very delicate grasp between thumb and finger, and is passed through the amalgam and, with one continued motion, right to the end of the canal, or until the shoulder engages the cavity margin at the point selected. This process is repeated several times carefully, until it is observed from the shoulder on the plugger that the amalgam is built up about 1 mm. at the apical end of the canal.

Gentle tapping will adapt the amalgam and condense it. The process is repeated, the amalgam being built up 1 mm. at a time until the desired amount—from 3 to 5 mm.—has been inserted.

The surplus amalgam is removed with barbed broach and the remainder of the canal filled with a combination of oxychlorid of zinc cement and guttapercha as follows: Having chosen a suitable guttapercha point, as large a one as will pass freely into the canal, we fill the rest of the canal full of a rather soft mix of oxychlorid of zinc cement and press the guttapercha point through it to the full depth. The surplus is wiped off with a hot ball burnisher, and, with a suitable plugger, warmed guttapercha is gently pressed into the cement. This will bring to the surface globules of mercury which have escaped the barbed broach. These should be removed from the tooth.

In order to prevent discoloration of the crown or visible neck of the tooth, the root filling should be removed to a safe depth (from 4 to 5 mm.) rootwise of the gum margin with a burr in the engine, and the walls of this portion of the canal made perfectly clean. The portion of the root filling thus removed is replaced with oxychlorid of zinc cement.

The placing of the guttapercha cone in a portion of the canal, as described, makes it possible to gain easy access to the canal for the insertion of a dowel, as in the construction of a crown, should that be necessary at a later date.

Radiograms should be taken immediately after the copper amalgam is inserted and before the cement and guttapercha are inserted, to check up the work and to satisfy the operator that it has been placed where he wishes it to be. In the event that he has failed to get it to the end of the canal, it can easily be removed because it is very slow in setting, taking hours to harden. Even after it is set, it is possible to remove it with a hot probe.

Copper amalgam can be successfully placed in any root canal in which guttapercha can be placed and has a decided advantage over it because of its proven germicidal qualities of a permanent nature.

Should any be pressed beyond the apical opening, it will be found to be non-irritating, except in a mechanical way, on account of pressure. This is only temporary, however.

Copper amalgam has been successfully used for a number of years as a root-end capping after root resection, but it would seem a simpler and much more effective method to fill the apical portion from the coronal end, provided the canal could be opened.

On account of the germicidal influence extending some distance on all sides of copper amalgam, it would seem permissible to place the amalgam 0.5 mm. or more short of the apical opening rather than press it through. Such investigators as Clyde Davis, of Nebraska, have shown, chiefly in devitalization cases, that the peridental membrane closes over the apical opening and even deposits lime salts in the opening, thus effectively sealing it. Any operation, therefore, that would permit of this physiologic repair would seem to be acceptable.

The vulnerable portion of a root canal is at the apical end because of the difficulty of closing the foramen or foramina.

Crownwise of these, the junction of the dentin and cementum—dentino-cemental junction—is, as it were, a fire wall, impenetrable and forming a barrier to the ingress or egress of organisms. Therefore, at least one of three things, it would seem, must be accomplished in dealing with these foramina in order to make a root canal operation a success:

1. Induce, if possible, physiologic closure of these foramina. (Davis.)

2. Mechanically obliterate (or fill) them.
3. Maintain asepsis of a permanent character in that area without causing irritation to the periapical tissues.

Briefly consider these in order:

1. *Physiologic Repair*.—Copper amalgam placed close to the end of the canal, after careful preparation, will permit and not hinder this repair because of its germicidal and non-irritating properties.
2. *Mechanical Obliteration*.—This is well nigh physically impossible, except in roots with a single foramen. A solution of rosin and guttapercha in chloroform cannot be relied on since the solvent becomes disseminated and leaves but a fraction of the original bulk in the spaces that it was supposed to fill. Neither can precipitated silver or any other precipitated material mechanically obliterate. The deposit, at best, is a porous mass.
3. *Maintenance of Asepsis*.—Since physiologic repair is uncertain, as is also mechanical obliteration, various medicated filling materials have been depended on. The main difficulty encountered with these is that they sooner or later lose their antiseptic properties and themselves become infected together with the surrounding tissues. Not until Fraser's work in the University of Toronto on "A Study of the Efficiency of Dental Fillings" was the fact demonstrated that, of all filling materials, copper amalgam alone possessed permanent germicidal value.

This fact, together with the findings of Miller, quoted at the beginning of this paper, viz., that dentin from extracted teeth which had been filled with copper amalgam was not only sterile but had antiseptic properties also, placed copper amalgam in a very favorable light as an ideal material to use in that vulnerable portion of the root canal—the apical end—provided it could be successfully inserted.

It is not only very adaptable physically and, what is important, impregnates the surrounding tissues with its benign antiseptic properties, making the surrounding dentin thus impreg-

nated actively germicidal, but, above all, it maintains this condition permanently. Nature, then, must be relied on to regenerate the periapical tissues. Clinical results have amply verified this.

1. Teeth with large areas were kept under treatment as long as eighteen months, or until the areas cleared up, and were then filled, and have remained clear.
2. Teeth with large areas, some with sinuses, were given short treatment during the time of canal preparation and cleared up *after* being filled with copper amalgam.
3. Teeth that had remained tender for months under bland medical treatment lost their tenderness in from a few hours to a few days after the insertion of a copper-amalgam root filling.
4. Copper amalgam carefully placed over punctures in roots or in the floor of the pulp chamber gives satisfactory results.

Permit me, in closing, to emphasize the necessity for the most painstaking care in the preparation of the canal, in the insertion of the filling, and in the checking up of the work, as it progresses, with the radiogram.

Dr. A. E. Webster, in an article, "The Root-Canal Question Put On a Scientific Basis," published in the March, 1932, issue of "The Dental Cosmos," says: "The two important considerations in filling a canal are, first, to maintain a sterile condition, and second, the more important, to leave no condition that will now or hereafter favor the growth of pathogenic bacteria."

He says, under the heading, "Properties of a Perfect Root-Canal Filling Material":

- "1. It should be liquid during the period of insertion and become solid a few minutes afterward.

Experiment.—Mix up a mass in the proportions recommended, and note how quickly it hardens. The rosin is soluble in either alcohol or chloroform, and when the solvent evaporates the rosin is left as a binder of the mass attached to the walls. (See experiments of Weston Price.)

"2. It should not be capable of irritating vital tissues. Neither oxide of zinc nor rosin have been shown to be irritants to human tissues.

(See experiments of W. D. Miller on copper amalgam; Jane Fraser on cements and amalgams; observations of F. C. Husband on copper amalgam; observations of Callahan on rosin; and experiments of Buchanan on dogs, not yet published.)

"3. It should be so sparingly soluble in the fluids of the body that it is undetectable by chemical tests, but detectable by bacteriological tests.

"4. It should be impermeable to both bacteria and moisture.

"5. It should hermetically seal a root canal.

"6. It should be permanently aseptic or antiseptic.

"A formula for a suitable root canal-filling material is:

Oxide of Zinc (bulk), 80 parts.

Rosin (binder), 17 parts.

Powdered Copper Amalgam (antiseptic), 3 parts.

Alcohol, q.s. to make thin paste.

"This compound meets all the preceding requirements."

Under the heading, "Selection of a Suitable Root-Canal Filling Material," Dr. Webster says: "Among all the root-filling materials mentioned, and scores of others that have been used, but should never again be mentioned except as a matter of history, there are but two types that fulfil the requirements set forth in a former paragraph. Root canals of normal size and accessibility in which the pulps have been recently devitalized and then completely removed under aseptic precautions, and where no moisture or irritation exists at the apex or in the periodontal membrane, should be filled with a mechanical root-canal filling or an antiseptic mechanical filling. Root-canals which have been the seat of one or more acute attacks of infection or long standing infection might well be filled with an antiseptic root-canal filling. Of the thirty or more materials and combinations of materials which we have tested, only two types meet the requirements of a permanent antiseptic, non-irritating

and mechanical barrier to moisture, namely, (1) pure copper amalgam and (2) rosin solutions in oxid of zinc."

There are four approved methods suggested for inserting the paste into the root canal:

1. Agitation. Carry paste on a smooth or slightly roughened broach into the canal, agitating the broach while inserting it to full length of canal, as well as when withdrawing it.
2. Plunger. Carry paste on a smooth, square-ended plugger into canal, using a pumping motion.
3. Corkscrew. Carry paste into canal on a spiral reamer and rotate reamer reversely while in the canal and while withdrawing.
4. Paint Brush. Twist a small wisp of cotton on a slightly smoothed barbed broach and with brushing motion paint paste into place. This is specially applicable to deciduous teeth.



The Problem of Fac-simile Reproduction of Anterior Esthetics in Full Denture Prosthesis



By Frank M. Lott, D.D.S., B.Sc. (Dent.)

A Thesis Entered in the Competition Held by the Canadian Dental Association
for Dental Research, 1931

BULLETIN NUMBER SEVENTEEN

ISSUED BY
THE CANADIAN DENTAL RESEARCH FOUNDATION
1933

The Problem of Fac-simile Reproduction of Anterior Esthetics in Full Denture Prosthesis



By Frank M. Lott, D.D.S., B.Sc. (Dent.)

A Thesis Entered in the Competition Held by the Canadian Dental Association
for Dental Research, 1931

BULLETIN NUMBER SEVENTEEN

ISSUED BY
THE CANADIAN DENTAL RESEARCH FOUNDATION
1933

CERTIFICATE

The Committee of Examiners is hereby assured that the work in connection with the accompanying thesis has been done solely by the writer.

The tooth blocks and dentures used as illustrations were constructed by him for his patients and the technique was developed without outside help.

Only one article by Dr. R. N. Harper, Dental Items of Interest, LII, 1930, pp. 397-400, refers to such a method, but, since most of the tooth blocks and dentures photographed by the writer for this thesis are at least three years old, the technique had been in use for a considerable time before Dr. Harper's article appeared last June.

F. M. LOTT

Oct. 30, 1931.

A. D. A. MASON

The Canadian Dental Research Foundation

is the official Research Organization of the Dental Profession in the Dominion of Canada, two Directors being appointed by the Dental Board of each Province, and two Directors appointed, ex-officio, by virtue of their office in the Canadian Dental Association.

All subscriptions are forwarded by the Secretary to the National Trust Company, Trustees, the interest only being used in support of research work in the several Dental Colleges of Canada.

This Bulletin is the Seventeenth of a series of Bulletins to be issued by the Foundation. Complimentary copies of all Bulletins issued will be sent to Canadian Dental Practitioners.

Any Dentist in Canada who feels that he has any original work worthy of publication is requested to forward it to the Foundation.

Copies of this Bulletin may be obtained from the Secretary, Canadian Dental Research Foundation, Room 312, Medical Arts Bldg., 86 Bloor St. W., Toronto, Canada.

Bulletins Published by the Foundation:

- No. 1.—The Evolution of the Pus Pocket, May, 1921, H. K. Box. (31 Pages, 27 Illustrations.)
- No. 2.—The Rupert Hall Method for Entire Upper and Lower Dentures, July, 1921, W. E. Cummer. (50 Pages, 38 Illustrations.)
- Nos. 3 and 4.—The Dentinal Cemental Junction; Histological and Histo-Pathological Studies of the Dental Pulp, May, 1922, H. K. Box. (60 Pages, 82 Illustrations.)
- No. 5.—The Science and Practice of Partial Denture Service, with Special Reference to a Graphic Method of Design, May, 1922, W. E. Cummer. (27 Pages, 16 Illustrations.)
- No. 6.—Combinations as an Aid in the Discovery of Fundamentals in Dentistry, and Other Sciences, May, 1923, W. E. Cummer, G. R. Anderson, Robert J. Reade. (71 Pages, 120 Illustrations.)
- No. 7.—Studies in Periodontal Pathology; The Mechanics of Occlusion, Summary of the Signs of Incipient Periodontal Disease (issued in conjunction with the Department of Health, Province of Ontario), May, 1924, H. K. Box, G. R. Anderson. (120 Pages, 135 Illustrations.)
- No. 8.—Articulation for Partial Dentures with the Snow Apparatus and Wadsworth Incisor Guide, June, 1924, W. E. Cummer, I. H. Ante, J. A. Bothwell. (45 Pages, 39 Illustrations.)
- No. 9.—Combinations which Occur Between the Upper and Lower Six Posterior Natural Teeth in Occlusion, June, 1924, W. E. Cummer, R. G. Anderson, R. J. Reade. (18 Pages, 13 Illustrations, including folded Chart.)
- No. 10.—Treatment of the Periodontal Pocket (issued in conjunction with the Faculty of Dentistry, University of Toronto), September, 1928, H. K. Box. (124 Pages, 120 Illustrations.)
- No. 11.—Impressions in Partial Denture Service (presented at the Ontario and Canadian Dental Associations, 1926, and reprinted, with additions, from "Dental Cosmos," September, 1926; December, 1927; January, 1928; March, 1928; and January, 1929), October, 1929, W. E. Cummer, R. J. Reade. (70 Pages, 76 Illustrations.)
- No. 12.—Special Cavity Preparations and Casting Processes for Gold Inlays, Including Some of the Physical Phenomena Taking Place in the Materials Used, and Methods of Compensating for the Shrinkage of Gold, January, 1929, H. E. Bulyea.
- No. 13.—Ultra-Violet Rays, Their Application in the Practice of Dentistry, 1929, Robert J. Reade.
- No. 14.—Necrotic Gingivitis (Trench Mouth), 1930, Harold Keith Box.
- No. 15.—Trismus Due to the Involvement of the Mandibular Nerve, 1933, S. W. Leslie.
- No. 16.—A Process for Production of Copper Amalgam from Ingredients in Aqueous Solution, 1933, F. C. Husband.
- No. 17.—The Problem of Fac-simile Reproduction of Anterior Esthetics in Full Denture Prosthesis, 1933, Frank M. Lott.
- No. 18.—Periapical Tissue Changes in Teeth of Dogs, Following Various Methods of Pulp Removal and the Use of Various Common Drugs, 1933, G. A. Buchanan.

CONTENTS

	Page
CHAPTER I.—GENERAL INFORMATION	
Tooth Form	9
Color	10
Size	10
Arrangement	11
CHAPTER II.—INVOLVED TECHNIQUE	
Ordinary Denture Service	13
Immediate Denture Service	18
CHAPTER III.—PRACTICAL APPLICATIONS OF THE TOOTH BLOCK TO ESTHETICS	
Number of Teeth	23
Size	25
Shape	27
Shade	32
CHAPTER IV.—MECHANICAL AND BIOLOGICAL FACTORS INVOLVED	
Protrusive Bite	35
Lateral Bites	40
Denture Space	40
Alveolectomy	42
Biological Factor	43
Psychological Factor	43
Phonetics	43
SUMMARY	45

INTRODUCTION

PERSONAL appearance influences a great many of the major activities of our daily lives. Sacrifices of time and expense are made at its altar; pain and even hunger are undergone to enhance it.

No greater component than the teeth exists for no beauty can survive their loss.

Herein lies a challenge for the progressive prosthetist for, no matter how skilfully function may be restored, no amount of persuasion will convince a modern woman that the dentures are satisfactory if appearance has been unduly sacrificed. Truly, the problem is a worthy one.

Research in any field must be preceded by a thorough familiarization with existing conditions and techniques. Then, in dentistry, the selected problem is frequently attacked experimentally and an improvement on a known technique or, in some fortunate instances, a new technique is developed.

In the following pages, the writer is, of necessity, repeating parts of processes already in use, but is doing so with all due respect to the large group of earnest men responsible for the development of them. It is hoped, however, that the incorporated deviations and additions will be regarded as some small contribution to the store of dental knowledge on the perplexing problem of dental esthetics.

F. M. LOTT

Toronto, Oct. 28th, 1931.

Chapter 1.

GENERAL INFORMATION

FOR descriptive purposes, the subject of dental esthetics may be resolved into four main divisions: the form, color, size and arrangement of the artificial teeth. Subdivisions, such as face form, arch form and profile, will be included in their proper order.

TOOTH FORM.—Among the older authors, Prothero (1) and Wilson (2) adopted an empirical classification of patients by temperament and proposed certain tooth forms and shades for the various groups. But the explanations were not very definite and the modern tendency has been to divide the subject and attempt separate solutions of the mould and shade problems.

In 1903, it had been drawn to attention by Dr. Berry (3) that the form of the upper central incisor could be related to the shape of the face. Continuing along the same line of reasoning, Dr. Williams, in 1911 (4), suggested a classification of face forms into square, tapering and ovoid divisions and the Trubyte tooth was introduced as a result of his work.

But this classification was, after all, an arbitrary one and Dr. Clapp, even though interested in the financial application of it, made the following statement in his discussion of a paper by Dr. Kirk (5):

“Nature seems to have lost control . . there is no longer any necessary relation between the type of face and the type of tooth. While there are many examples of harmony, there seem to be even more of disharmony.”

Anthropological authorities have always questioned the Williams classification and, while Dr. Clapp would justify it by inferring that Nature did control the situation at one time, all parties are apparently now agreed as to the vulnerability of it.

COLOR.—The color division of the problem was advanced to a certain point. The Twentieth Century Shade Guide has been practically a standard for a long time and no perceptible interest was being taken in this branch of dental esthetics. But, recently, the same manufacturer has introduced an improvement based on a classification by complexions without any mention of the temperaments that were so often used as a basis by the older men. Spectral analyses were made of characteristic natural teeth in the mouth to scientifically determine their color components. The new color guide certainly marks an advance, and the company is to be congratulated on this timely application of spectroscopy to a difficult problem.

SIZE.—The size of teeth for full dentures has always been a question. However, it has been simplified by newer techniques and to a certain extent by the tooth manufacturers.

The operator trims the occluding surface of the upper bite block to a proper relation with the upper lip in repose. The length of the upper central is then represented by the distance from this occluding surface to the high lip line. The angles of the mouth are then marked. In a majority of cases the distance between these two points may be taken as the combined width of the upper six anteriors. With these measurements at hand, a proper size may be selected by using the mould guide and literature supplied by the company.

But, again, there may be difficulty. One or more attendant conditions may involve all three of the foregoing divisions. Thus, one author complains that

“By far the largest percentage of those for whom we make dentures are past middle life, and yet the teeth furnished us by manufacturers to place in their mouths are the teeth of youth, showing none of the evidences of age or wear or pathology. It is impossible to avoid a feeling of incongruity when we are forced to place these youthful specimens in the mouths of elderly patients.” (6)

All of which is true, but where is the solution? Most dentists will agree with Dr. Orton that

"The number of these markings is infinite or indefinite. They are not alike in any two mouths. They vary in the individual teeth in any given mouth. The stock required to produce any considerable fraction of the vast number of these variations as found in Nature would be far beyond the capacity of any retail dealer to handle. But if such a stock could be accumulated, it is highly probable that a dentist might spend a whole day in going over such a stock without finding a suitable match for the defects, special markings, stainings or other peculiarities of the case in hand." (7)

The dental manufacturer takes the very practical stand that, when the dentist knows what he wants, it will be produced for him. In the meantime, teeth will continue to be made to the present arbitrary but fairly comprehensive system of forms, sizes and color combinations, and it will remain necessary for the dentist to select the nearest approximation to his requirement and then exercise his ingenuity in the production of the desired esthetic effect.

ARRANGEMENT.—There still remains this last division; a problem so complex as to have more or less defied advance. The arrangement of the anterior teeth so involves esthetics with mechanical and biological factors that it constitutes a continual stumbling block for the dentist seeking to give the most appreciated service.

Many articles have been written on this subject of tooth arrangement with its involved factors, such as arch form, face form and profile, but the information contained is usually of a very general character. Thus, the attitude of many is well stated in a recent article by Dr. Asche:

"Avoid getting too regular a set-up . . . when you arrange them in this way they are sure to advertise their presence by an unnatural look." (8)

Dr. Arata advises a characteristic set-up for the various types. He states that

"The typical arrangement of the six front teeth is governed by the mould selection and the shape of the occlusal plane." (9)

However, this opinion is, apparently, not general.

With the verity of the Williams theory in the balance, there is still less reason to assume that there is a possible classification of anterior arrangements of teeth characteristic of or in accordance with a more or less hypothetical foundation. Certainly, one such recent and fairly extensive classificatory attempt in the Research Department of the University of Toronto (10) brought to light nothing more than some interesting observations. And that, in general, is the attitude of most of the authors. The problem, then, is far too extensive to be confined to any system at the present time.

But there is a solution for that patient under the care of the prosthetist before the teeth have been extracted. If there is no existing law and, therefore, if each case is a law unto itself, then there is no doubt but that the typical arrangement of artificial teeth for any particular patient is the duplication of the arrangement of the natural teeth prior to extraction.

And the same statement applies to the three foregoing factors of form, color and size. After all, esthetics is but harmony, and, in the face of all the unknown elements involved, it would appear truest harmony to duplicate pre-extraction conditions to a great extent and thereby render the prosthetic appliance as inconspicuous as possible.

Discriminating patients comprehend this reasoning at once and appreciate any effort at duplication because they feel that the dentist has been governed too much by precept in the setting up of teeth. Dental training leaves little to be desired as regards mechanical efficiency in the arrangement of anteriors, but the appearance, in many cases, is anything but satisfactory to the patient.

All of these four divisions will be taken up in detail, but only for that class of patients in the hands of the prosthetist prior to extraction. The already-edentulous patient presents an entirely different problem that is quite outside the scope of the present article. Further, full denture conditions only will be treated. It is assumed that the reader will readily make his own applications of the technique to other dental work.

Chapter II.

INVOLVED TECHNIQUE

IN the first applicatory reference with which the writer is familiar, an old textbook on Prosthetic Dentistry published in 1859, but details of which are unavailable, it was stated that the happiest esthetic result was obtained when the arrangement of the artificial teeth exactly duplicated pre-extraction conditions. The author made no attempt to explain how this might be accomplished. The statement was apparently put forward merely as a suggestion and the result secured by the dentist would be purely a measure of his memory of these pre-extraction conditions and his capability of reproducing them.

Several years ago the writer was confronted with an interesting situation while visiting in the office of a fellow practitioner. A patient had insisted on dentures with teeth of exactly the same size as his natural teeth and the young dentist had attempted it without hesitation. The result cannot be expressed in the dentist's own words. But he learned very definitely and in a rather costly manner that the experienced prosthodontist usually selects teeth of a slightly smaller mould than the natural teeth to be replaced.

The dentist argued that the extraction of a tooth left a space into which it should be possible to fit an artificial tooth of the same size and shape. The writer had accepted the above rule regarding the use of a smaller tooth because older men had passed it on as good advice, but the challenge caused him to begin an analysis which is resulting in the present article.

Duplication can be successfully accomplished in both ordinary and immediate denture service techniques. The two will be taken up in this order.

ORDINARY DENTURE SERVICE.—A very good method of beginning full denture work is to extract all the posterior teeth first. The order and rate of removal may be arranged according to oral and systemic conditions as well as to the

convenience of the patient. This allows the healing of the larger posterior sockets and absorption in general to proceed to a point where the mouth is almost or quite ready for the taking of impressions. It is to be recommended because, during this interval, the patient still has some small measure of masticating efficiency, proper jaw relations are generally maintained and the condition, as a rule, is not embarrassing to the patient from the standpoint of appearance.



FIG. 1. COMPLETED TOOTH BLOCK

When possible, the anteriors are then extracted at one sitting. Usually, the anterior ridges are quickly in a condition to permit of the taking of impressions, and the pre-denture interval is, therefore, relatively short and highly appreciated by the patient.

Before the removal of the anterior teeth separate compound impressions are taken of upper and lower groups in ordinary crown and bridge trays. A wax bite is then taken and the patient is ready for extraction.

In those cases possessing heavy undercuts, the accuracy of the labial surface of the impression should be maintained at the expense of the lingual. In other words, remove the impression by deliberate distortion of the lingual surface.

After extraction, the teeth are thoroughly cleaned, sterilized, and about one-third of the root of each is usually cut off to minimize the size of the completed cast. They are then accurately seated in the impression with regard to the labial aspect and the latter is poured in plaster.

After separation, the two casts are related to each other with the aid of the wax bite and are united by more plaster. Later, the wax is removed and the cast is carved to a pleasing shape and given a couple of coats of shellac. Fig. 1 is an illustration of such a tooth block.

It is now ready to yield the necessary measurements when the bite is being taken.

When carefully made, it is quite presentable in the operating room, the patient can be assured of the now-aseptic condition of the incorporated teeth and it is a most convincing proof of the mechanical efficiency of the progressing denture work.

The first use of this cast is to aid in the establishment of the occlusal plane. The old rule that the central should be placed two millimetres below the upper lip in repose is a very average approximation only. Indeed, it appears at times that the exceptions outnumber the cases to which the rule correctly applies. The upper bite block is first trimmed in its horizontal dimension until it is approximately parallel to the line from nose to ear. The vertical dimension is then determined as follows: the length of an upper central or, in some cases, the longer central is measured on the tooth block with a pair of calipers. Then the indentation of the crest of the labial bone of the same tooth is identified on the inside of the bite block and a measurement taken from this point to the plane so far established. The bite block is then altered in height until the two measurements are equal. At times, an allowance must be made because of post-extraction trimming of the alveolus or, in doubtful cases, another indentation, such as made by the lingual aspect of the bony septum at the median line, may be substituted. In either case, the result is generally a close approximation.

Due to many overbite conditions, the height of the lower block often presents difficulty also. This time, the cast is

measured from bony landmark on the lower ridge to the incisal edge of the UPPER tooth measured in connection with the upper block and the lower block is then trimmed accordingly.

The appointment may then be concluded by securing any customary registrations, but without the necessity of deciding upon the shade and mould of the teeth or marking the angles of the mouth or the high lip line.

The teeth are selected as the next step, but in the laboratory rather than at the chair. Ordinarily, the central is measured on the tooth block and a mould of similar size and shape chosen by it. But exceptions arise also. For instance, over-size centrals, peg laterals or other abnormalities may be encountered and necessitate the use of more than one mould. Or again, it may be impossible to select a satisfactory mould. In such cases, contrary to the general rule, it is at times advisable to select a larger type of tooth in order that the bulk of porcelain will permit of the necessary grinding.

The shade of the tooth is very easy to decide upon at this juncture. The only requirement is that it be lighter than the prevailing shade of the natural teeth being replaced. With this technique, where the closest possible duplication is being attempted, staining is resorted to later.

The next service rendered by the tooth block is during the setting up of the artificial teeth.

In beginning the description, it is assumed that the casts have been mounted on the articulator and that the latter has the incisal pin in position and all adjustments set.

A piece of thin gauge tin foil with a rounded peripheral rim of wax and a reinforced palate is sealed to the upper cast. The lower bite block with median line marked on it is sealed to the lower cast. The tin foil is to be recommended for the following reasons:

1. It prevents the set-up from adhering to the cast.
2. The close adaptation of the tin foil to the cast gives the operator a clearer view of his set-up problem than can be procured by excavating a bite block to place each tooth in position.

3. The bite blocks are thus preserved, a great advantage if the repetition of any registrations is required.
4. The bright, clean foil creates a favourable impression at the try-in appointment.

Setting up the upper anterior teeth is very easy to describe but the actual operation often takes considerable time. One central is first ground to the size and shape of the corresponding natural tooth. A small cone of wax then sticks it to position on the tin foil. It is then adjusted exactly to the median line as marked on the lower bite block and tilted labio-lingually or mesio-distally as demanded by the tooth block beside the operator. The other five upper anteriors are then waxed to position in a similar manner.

Upper and lower posteriors are next set up.

Then come the lower anteriors and some attendant problems. At this juncture, it is sufficient to state that they are set up by the same technique as the uppers. But here the overbite is encountered, and, occasionally, it is quite difficult to reproduce the desired esthetics and, at the same time, make the lower anteriors function properly in lateral and protrusive bites. This condition will be taken up later, but, at this time, it may be recalled that by far the greater amount of attention is always directed upon the upper denture, and that, in those cases where it is necessary to deviate slightly from the above technique, the liberty can almost always be taken at the expense of the lower set-up without fear of detection.

The final service of the tooth block is to aid the operator in the staining of the teeth. There is not a doubt in the mind of the writer but that this is the crowning touch in the esthetic reproduction of anterior conditions and is well worth any effort required for the mastery of it.

The reader interested in stain manipulation is referred to literature of the S. S. White Co. (11) and the Columbus Dental Manufacturing Co. (12). The technique is considered outside the scope of the present work but there are some points about which the reader may be reassured. For instance, it is claimed that, in some cases, the pins pull out of stained teeth. The fusing point of the stain, 1600 deg. Fah.,

is undoubtedly above that of the solder about the pins. But, that the union is not weakened too greatly, is well proven by the experience of the writer that hundreds of teeth have been stained with practically no trouble due to the breaking away of the pins. On the other hand, it is felt that much staining is being done with inaccurate pyrometric equipment and that the temperatures at which the stain is fired are often excessive. If the pyrometer is accurate and the stain fired at exactly 1600 deg. Fah. for two minutes, very little trouble will be experienced.

There is also a belief abroad that the stain wears off after a time. Apparently, there is a tendency for this to happen in some mouths. On the other hand, if the teeth are also glazed with 1600 deg. Fah. glaze after having been stained, it is an extra and, usually, an effective safeguard against such an occurrence.

IMMEDIATE DENTURE SERVICE. — For the bank manager who is confronted with a full denture problem and who must be back at his desk Monday morning, the minister who must face his congregation the next Sunday, or the lady who just cannot forego her bridge or golf, immediate denture service is a splendid dental measure.

This technique has, of course, been used by the profession for some time, but the present modification is felt to be superior because more exact duplication of anterior conditions is attempted.

Posterior extraction is again to be recommended as a prefatory step.

Then, when the mouth is in a suitable condition to proceed, sectional compound impressions are taken. For detailed instructions in this technique, the reader is referred to such works as those of Dr. Roach (13) and Dr. Scott (14).

In the interval before the next appointment these are boxed and the stone casts made. Also, partial bite blocks are made up for upper and lower casts.

The operator is then in a position to establish the plane, secure centric relation, etc. But, again, shade and mould of

tooth, high lip line and angles of the mouth are disregarded and, this time, the median line as well.

In the laboratory, the related casts are mounted on the articulator and the latter is adjusted. The upper bite block is then removed as before and the tin foil burnished, sealed to place and the palate reinforced. The lower bite block is again sealed to the lower cast and the setting up of the posterior teeth is proceeded with.

The two posterior partial set-ups are next tried in the mouth and checked for centric relation, lateral movements and the functional protrusive movement indulged in by the patient.

The advantages of the presence of the anteriors up to this point are obvious. They aid in the establishment of the plane, definitely assure centric relation in the great majority of cases, and assist in the checking up of the various mandibular movements during the try-in.

But there do exist such abnormally prognathous or retrognathous cases that anterior contact is practically non-existent in centric relation. In such cases, extraction of the posteriors for any length of time before the removal of the anteriors sometimes results in an abnormal and more or less obstinate movement of the mandible due to a newly-found freedom or an effort to secure some small measure of masticating efficiency. The retention of one or more bicuspid or some such plan increases the number of contacts and is of service whether this type of denture work or ordinary technique is being attempted. However, abnormalities are often purely a question of the operator's judgment. A few of them will be discussed later.

The anterior teeth must now be set up. With this technique there is, of course, no tooth block except in a case, such as Fig. 2, where the patient was wearing an esthetically satisfactory partial denture incorporating anterior teeth. A snap impression was taken and the cast made up as illustrated.

However, this method was only possible because the patient consented to the loan of the partial during this set-up period. In fact, it had to be borrowed twice because the three anterior

teeth included on the partial were set up at the same time as the posteriors. The anterior situation was, under these conditions, taken care of in two instalments.

But while no block containing the patient's teeth is possible when the teeth are still in the mouth, it is not required when the operator is in possession of accurate casts.



FIG. 2

This method of replacing the teeth is well known in Dentistry, but the operator often brings the technique up to this point and then proceeds with the successive removal of the teeth from the stone cast and their replacement by an even row of similarly shaded porcelain teeth. This is immediate denture service, of course, but there is, as a rule, very little reproduction of anterior esthetics in it.

The following technique makes an attempt at greater accuracy. Assuming that suitable artificial teeth are at hand, begin by measuring a tooth on the cast and grinding the artificial tooth to the same size and shape. Slight grooves, notches and other imperfections may be left at this time. They belong to the field of esthetics and can be easily ground in just prior to staining.

Now, as illustrated in Fig. 3, draw a line up the long axis of a central on the cast and continue it up far beyond the tooth. Mark the gingival line on both labial and lingual surfaces and then cut the tooth out neatly with a fine saw as seen in Fig. 4. Cut a slight depression as a socket and wax the artificial tooth to position as per data marked on the cast.

The remainder of the set-up is merely a repetition of the above procedure.

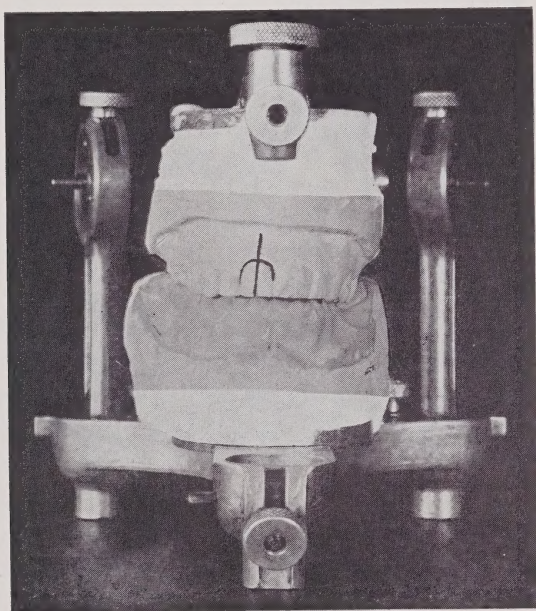


FIG. 3

As the work progresses from the esthetic standpoint the mechanical factor must not be lost sight of. Tooth by tooth it must often be ground in also.

And now an additional appointment becomes necessary. No try-in is possible, of course, but the patient must be brought in while the teeth are being stained.

From this point the technique reverts to common-place dental procedure, and need not be taken up.

Both methods of reproduction have now been described. But there yet remain problems regarding the various factors themselves, their relation to each other, the treatment of abnormalities, etc., that require consideration.

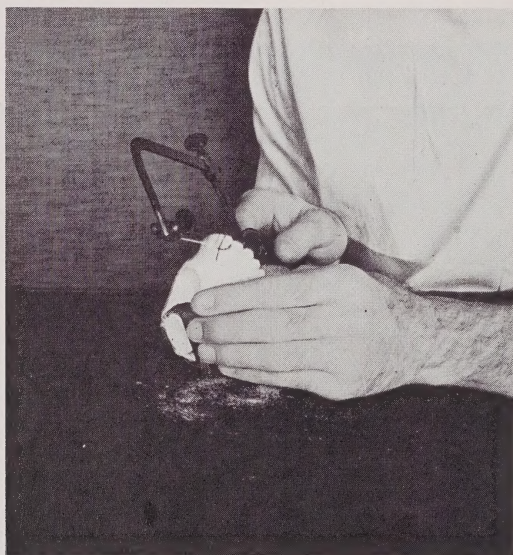


FIG. 4

Chapter III.

PRACTICAL APPLICATIONS OF THE TOOTH BLOCK IN ESTHETICS

THE question most frequently asked by dentists in connection with this method is as to whether the patient wishes the reproduction of all abnormalities.

The patient does and does not. There are very frequently one or more reasons for denture work in addition to infection. Unsightly fillings, badly discolored or malposed teeth, etc., may have caused the patient to more or less look forward to the loss of the natural teeth and to suggest the reproduction of such conditions would be bad policy indeed.

On the other hand, the writer has often found that the patient is inclined to want too much and would involve the operator in difficulties, particularly in the mechanical aspect of the work. The whole question is a matter for the judgment and skill of the operator.

The subject will now be discussed from the standpoint of actual experience, with illustrations of practical cases and the methods of treatment.

THE NUMBER OF TEETH. — This division of the subject occasionally causes the operator some thought. Fig. 5 is a good example.

The upper right cuspid and left lateral had been lost in early youth. The illustration is actual size and gives a good impression of the very narrow upper arch. Esthetics demanded duplication as far as possible, but what of the involved mechanics?

Such a set-up would place lower cuspids considerably distal to the position they would occupy normally and trouble would be experienced in correctly relating posterior teeth to this anterior condition. In this case, the lower left cuspid was about half its width distal to the upper. The lower first bicuspid was left out and the upper first bicuspid and lower cuspid ground to satisfactory relation. On the right side an upper cuspid was used. The anterior arc was of a flatter

curvature on this side. The tooth would, therefore, be more noticeable, and a cuspid was felt to be superior. The relation of the lower cuspid was still not correct for the adjacent posteriors, but a little grinding on the mesial surface of one first bicuspid and a certain amount of spacing of the opposing one produced an efficient result.



FIG. 5

Such is practically the story of all the cases. Patient and operator both wish the most harmonious esthetic result but the operator must keep the mechanical factor constantly in mind and not exceed the bounds of his better judgment. Fortunately, the tooth block is an efficient guide mechanically as well as esthetically.

Another branch of the same problem is presented in Fig. 6. This is really a bridge case but is included because it is the best illustration of the point in question.

Due to the heavy over-lapping, the space left by the extraction of the four anteriors was just correct for three teeth of the same size.

But the patient objected to any such regular arrangement. A high overbite further complicated matters. However, thanks to the block, the facings were ground in after sufficient trouble, to be sure, but with undoubtedly less than if the block had not been available.

Then there are cases, such as Fig. 7, where again there is a tooth missing. There is, however, no doubt about the replacement of it in this case. The loss of that particular lower incisor and the loose condition of its neighbor was the immediate reason behind the denture work for that patient. Fig. 8 is a photograph of the finished dentures in connection with the preceding illustration.

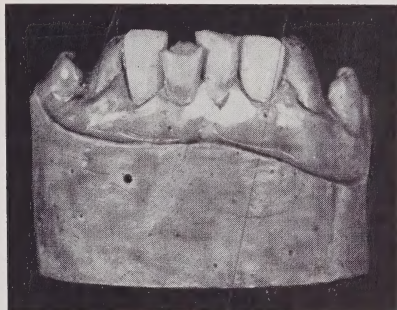


FIG. 6

This cut conveys a fairly good impression of the extent to which all four factors of form, color, size and arrangement are attempted. But it must also be pointed out that all the dentures were photographed under conditions quite different from those existing when the blocks were taken. Thus, the result does not always permit a suitable comparison in definition density and sometimes in size also. However, the general effect is there.

THE SIZE OF THE TEETH.—Fig. 9 well illustrates what the patient wants in some of these cases.

His brother, with an almost identical tooth arrangement, size of arch, etc., had had his denture work done without the guidance of a tooth block. The dentist was deceived by the small arch and placed in the denture small, evenly arranged anteriors. The result was not satisfactory. The brother wanted a condition reproduced and did not get it because of the lack of sufficient data. The effect went further, too, because the dentist lost at least one prospective patient on account of it.

There also exist many cases where teeth, such as over-size centrals, peg laterals, etc., require the use of more than one mould. Another example is where absorption is met with, as in Fig. 10. In extreme cases a larger mould of tooth is required to permit of the necessary grinding.

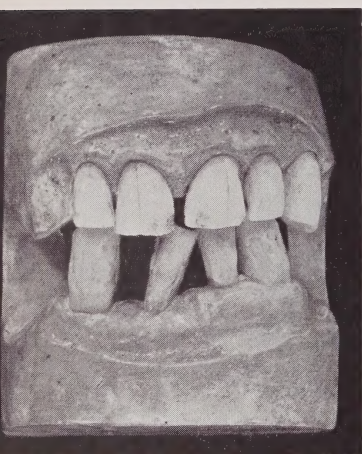


FIG. 7

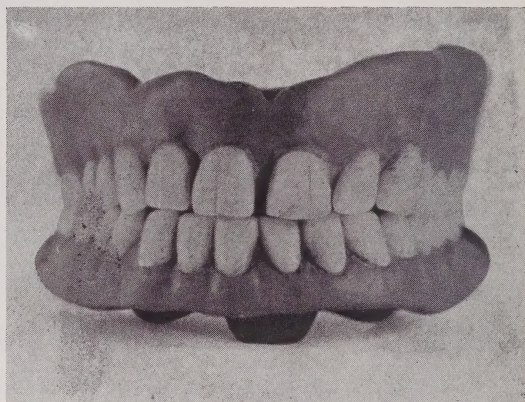


FIG. 8

However, no attempt was made to go the limit in reproduction in Fig. 11, which is a photograph of the dentures constructed from the tooth block of Fig. 10. The absorption about the neck of the upper left central and the length of the same tooth were disregarded. Consideration of the former was unnecessary because the patient's upper lip did not reveal it, the length was made the same as the other central to evade a possible mechanical complication.

On the other hand, there is no doubt about such a tooth as illustrated in Fig. 12. The patient simply would not tolerate it in a denture.

Nevertheless, the general effect was maintained in this case by the retention of every feature except the size of the upper right central, the number of fillings, etc.

THE SHAPE OF THE TEETH.—With this technique the shape of the teeth is not finally decided by the choice of a certain mould. They should be regarded as only semi-ready when they are purchased.

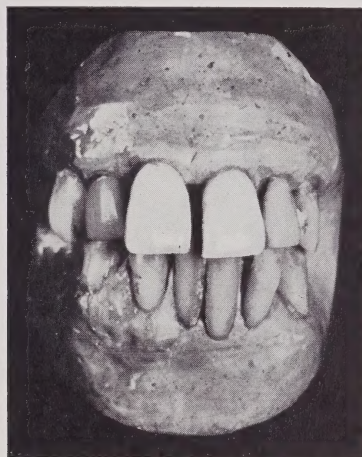


FIG. 9

The general contour should be ground to duplicate the natural teeth, and, where much grinding is necessary, the

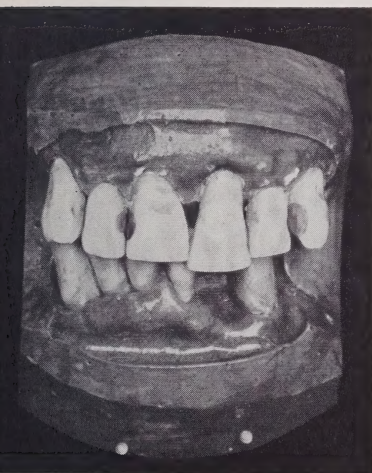


FIG. 10

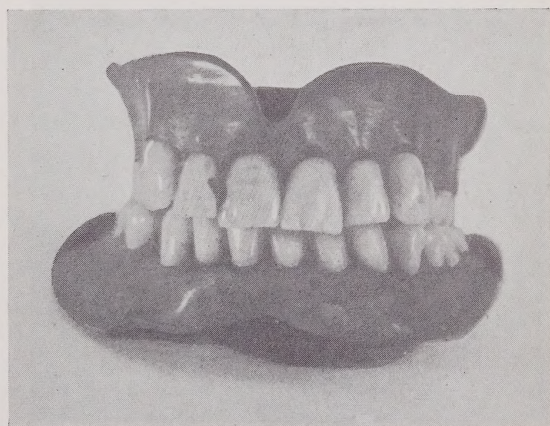


FIG. 11

surfaces should be finally smoothed up with a disk in order that they may be glazed with better results.

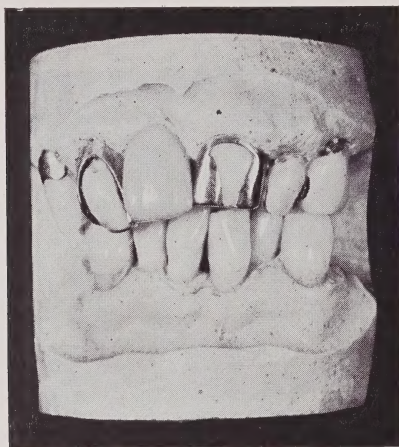


FIG. 12

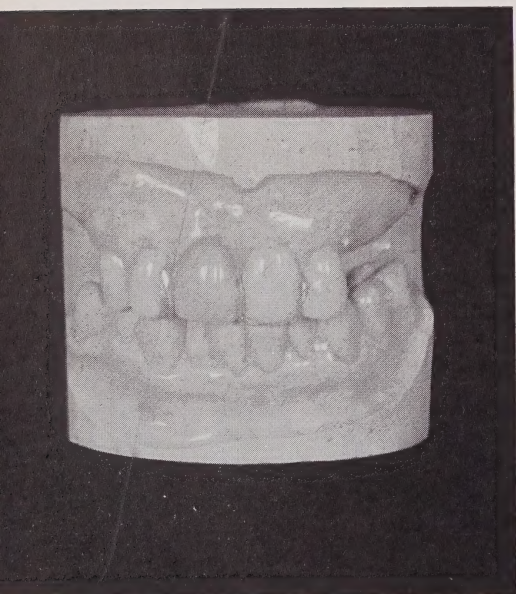


FIG. 13



FIG. 14

The reproduction of labial depressions, such as in the upper left lateral in Fig. 13 or near the incisal edge of the upper right central and the centre of the labial surface of the left central in Fig. 14, increase the natural appearance of a set-up generally.



FIG. 15

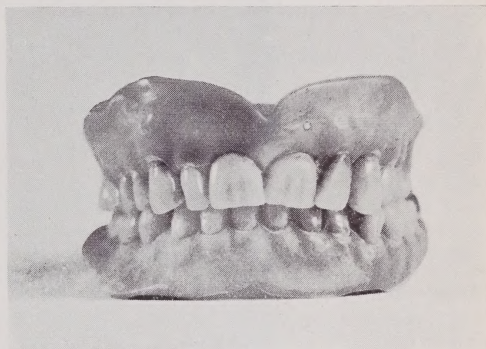


FIG. 16

Also, longitudinal and transverse grooves, as in Fig. 15, are effective.

Fig. 16 is an illustration of the dentures constructed for the Fig. 15 case. Only a slight attempt was made to duplicate the shape of the centrals in the gingival region. Again, the patient's lip did not reveal this part. There also appears to be more overbite in the dentures than in the natural teeth. This is a photographic point. The tooth block was tipped back slightly when the exposure was made, thus giving them a lengthened appearance.

Cracks, such as illustrated in Figs. 5 and 7, and slight fractures, as exemplified by the chip out of the upper right central in Fig. 17, are splendid, but the attempt must not be carried so far as to replace a mutilated tooth, such as the upper left lateral in Fig. 12, or a large cavity, as in the gingival third of the labial surfaces of both upper cuspids in Fig. 18.

Note the crack across the labial surface of the upper right central in Fig. 18. Much trouble has been experienced through the natural teeth drying and breaking. A Canada Balsam treatment is now being used, however, that hardens them beyond any such possibility.

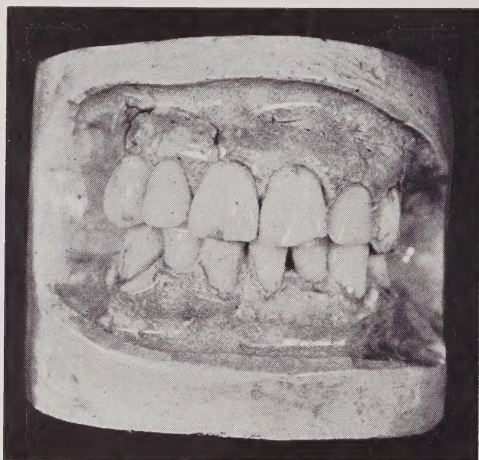


FIG. 17

Fig. 19 is a photograph of the dentures corresponding to the tooth block of the foregoing illustration. The lower con-

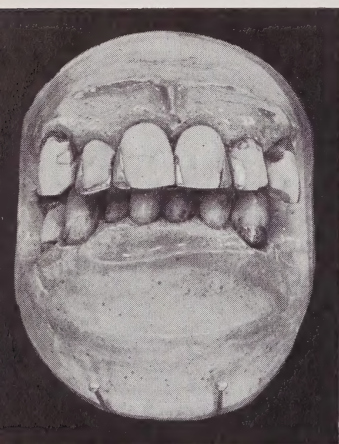


FIG. 18

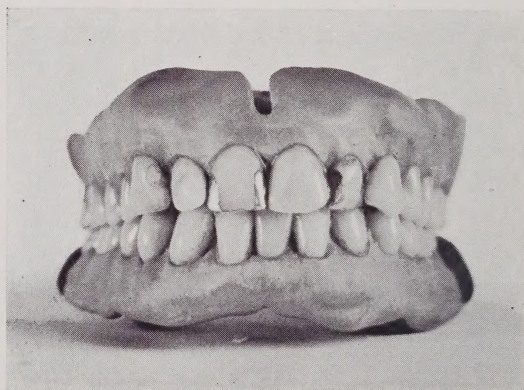


FIG. 19

ditions are quite different in the two figures, but the dentures are at least three years old and have been rebased and the lower anteriors reset.



FIG. 20

And that is what happens to many of the high overbites. They are slightly lower in the first dentures than in the tooth block, and the overjet is, perhaps, slightly increased. At rebasing time, they are lowered still more until they are, perhaps, almost the conventional overbite. The progressive lowering decreases the difficulty of handling the protrusive bite situation, and draws no protest from the patient because the change each time is not noticeable. Also, during the interval, absorption has provided the necessary additional space for the reset.

The labial surfaces have thus far received all the attention, but how about the lingual?

Fig. 20 explains the situation nicely. The upper right central, lateral and cuspid have been ground to produce a certain esthetic effect, but note how the lingual and incisal surfaces have also been ground to permit of the lateral bite. Again, it is a case of keeping the mechanics in step with the esthetics.



FIG. 21

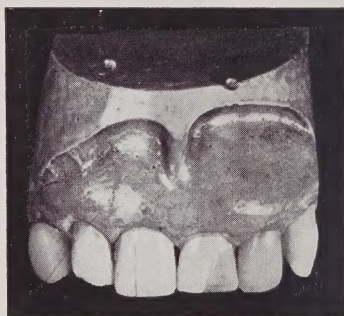


FIG. 22

THE SHADE OF THE TEETH.—Natural teeth are practically never as uniform in coloration as the artificial teeth purchased for the case. Therefore, some shading is almost always good procedure, but, again, it must not be carried too far. As already brought to attention, there are usually one or more reasons for the extraction of teeth and the discoloration of an odd one may be included in the list.

The various areas of stain and calculus, such as shown in Fig. 17, may well be copied. Blue spots are also effective. The teeth of Fig. 13 have fine blue areas on both upper laterals and the left central, but, unfortunately, they do not show in the photograph.

Fine fracture lines, as illustrated in a number of places, and gingival lines traced out, as in Fig. 21, are also realistic.

Synthetic fillings are highly appreciated. The upper left central in Fig. 22 is a fine example.

But no patient would wish for a tooth as dark as the upper right lateral in Fig. 9 or the upper left lateral in Fig. 1. If the operator is going the limit in reproduction, the dark tooth

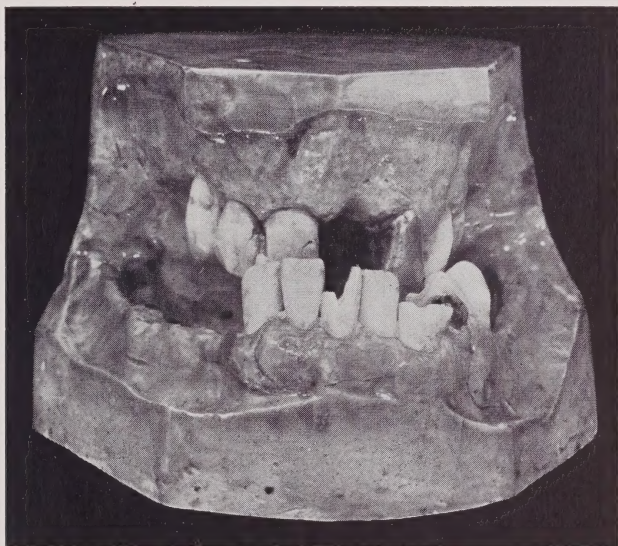


FIG. 23

should be included. But such is a good point to discuss with the patient. Mostly, a compromise is arranged and the artificial tooth is stained only slightly darker than the others in the set-up.

The question of fillings is also bound to appear. The replacement of a single filling, such as in the distal of the upper right central in Fig. 10, is usually fine.

The other extreme is, perhaps, represented by Fig. 18. In this case, note that two fillings only were used, Fig. 19, one on the upper right central and the other on the upper left lateral. It was considered sufficient to merely create an effect of anterior gold fillings. No attempt was made to reproduce the appearance of the amalgam fillings in this same case.

Thus, the open face crowns on the upper right lateral and left central in Fig. 12 were replaced by one large inlay on the central.

The patient whose tooth block is shown in Fig. 23, also the lady of the block, Fig. 1, were both persuaded against it.

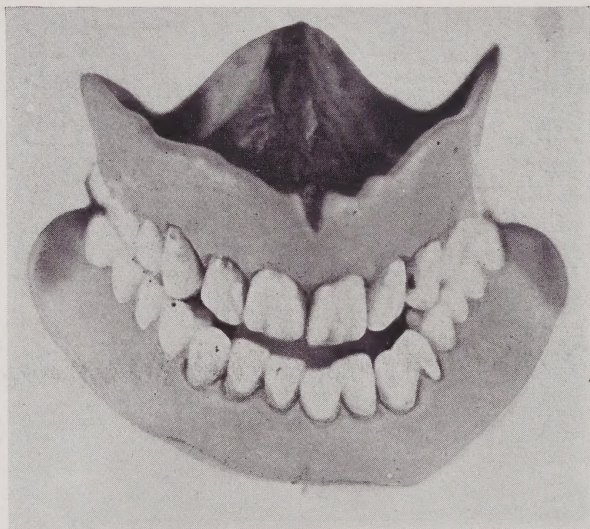


FIG. 24

Fig. 24 is a photograph of the dentures constructed in connection with the tooth block of Figs. 23 and 25. Very little time was expended on the duplication of surface markings, etc. The block is a good illustration of that type of case where the mechanics constitutes the chief worry.

The tooth block has now been rather fully discussed as regards esthetics. Surely it is agreed that the inclusion of such factors as over-lapping or spacing of teeth, the non-restoration of missing teeth, replacement of fillings, variation or alteration of size, mould and shade, etc., in a well-considered attempt to duplicate the natural conditions is an improvement over former methods.

Chapter IV.

MECHANICAL AND BIOLOGICAL FACTORS INVOLVED

THE PROTRUSIVE BITE.—This is one of the most important of the involved factors.

Dental Colleges and tooth manufacturers have long taught a certain conventional anterior set-up with just so much overbite. This is fine for efficiency in those cases with more or less of a normal jaw relation. But the writer was struck by the large number of patients whose jaw relations did not conform to such an average. Perhaps Fig. 14 is the best example of this average condition, while Figs. 25 and 26 are extremes of prognathism and retrognathism respectively.

Between these two extremes, the operator with but a single conception of an overbite must make many errors in attempting to apply it. Not only is the set-up applied to the jaw relation—the reverse also holds true in many cases and much alveolectomy is indulged in to surgically make the jaws conform to a required set-up condition.

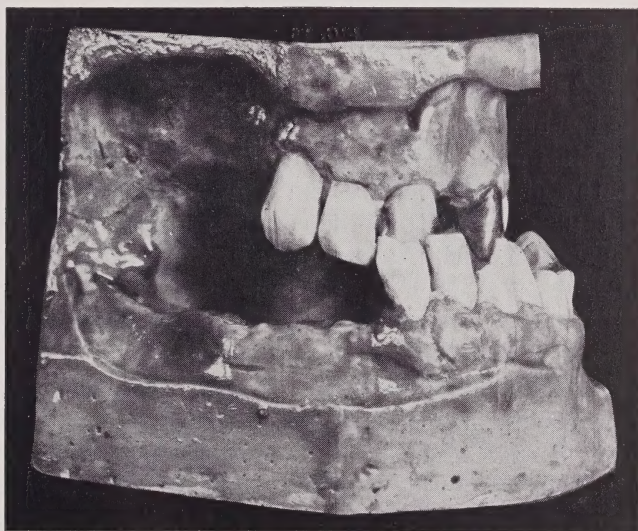


FIG. 25

But there must be a limitation to such arbitrary procedure. Without considering the two extremes illustrated, there is a great number of intermediate cases where the operator insists on, one might say, a mechanical overbite to the exclusion of esthetics.



FIG. 26

The writer feels that such reasoning is faulty. To begin with, the mechanics striven for is not always secured. Some cases, for instance, require the anteriors to be set off one ridge or the other to secure the conventional overbite. A lever is thus created that may cause trouble mechanically and biologically as well if a sore mouth, absorption, etc., result from it.

But there is no reason why the facsimile overbite cannot be efficient mechanically as well as esthetically in a great many cases. The following case, Fig. 27, may aid in explanation.

At first sight, an operator would usually suggest alveolectomy from cuspid to cuspid in the lower jaw and at once provide sufficient room for the lower incisors. But this patient had had three operations within a short time and refused the alveolectomy if any other method could be used. The

writer asked for time to think it over, and finally decided to try exact reproduction of anterior conditions.

In justification of an apparent infraction of a law of articulation he reasoned as follows. Here was a patient who had had a certain limited protrusive movement for many years. On a certain day it was intended to extract the

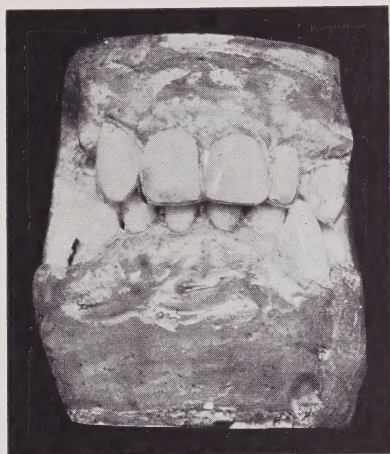


FIG. 27

anterior teeth and send the patient home with the dentures inserted. Was she suddenly going to require a standard set-up with a slight overbite that brought the anterior teeth into an end-to-end relation in the protrusive movement? At any rate, the case was proceeded with. The length of the protrusive movement was observed. A further safety margin was established in the set-up by slightly decreasing the height of the overbite and, at the same time, slightly increasing the amount of overjet.

The case was successful. Since that time, many others, some of which are among the illustrations, have succeeded and the writer has been led to form the following conclusion. Apparently, many patients with high overbites in their natural teeth do not come to an end-to-end relation at the extremity of the protrusive bite. This condition is shown in Fig. 28. There is certainly a definite movement incisally, but, at its

full extent, it leaves the incisal edges of the lower incisors still resting on or near the lingual surfaces of the upper teeth, although, of course, nearer the incisal edges of the latter. This, if built into dentures, is quite in accordance with the modern conception of occlusion. Balance is only demanded of the operator within the functional range of the mandibular movements.



Position A
Centric Bite

Position B
Protrusive Bite

Fig. 28.

In the artificial set-up, it is admitted that an exaggerated protrusive excursion would tend to unseat one or other of the dentures, but it would be a definite voluntary effort and indulged in no more frequently than any other abnormal movement that might produce the very same result.

But it is also felt that each case is a law unto itself. In other words, the writer would not care to attempt a high overbite on such a case as Fig. 27 without exact knowledge of that particular condition as gained by oral measurements and the use of a carefully constructed tooth block. The above case, by the way, was not really so difficult. The contact on the two lower cuspids is close, but the overbite is not great.

The lower incisors seem to be high indeed, but, although it cannot be seen in the photograph, there is a certain amount of overjet in connection with all four.

Fig. 29 is an illustration of the dentures constructed for Fig. 27, but photographed after they had been in use for three years, and during which time they had been rebased.

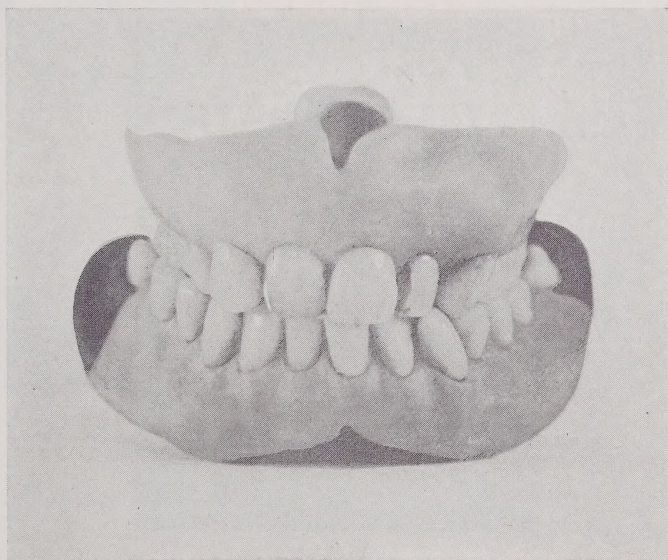


FIG. 29

Just as in the case represented by Figs. 18 and 19, absorption brought increased leverage, especially on the upper, and, at rebasing time, the overbite and overjet were decreased very considerably in connection with the four incisors. Absorption provided the necessary space to lower the incisors, and the patient was pleased to have evaded the necessity of alveolectomy.

Mechanically, it is felt to be good technique to reduce the overbite condition. After all, contacting surfaces should be as nearly as possible at right angles to the axes of the teeth, whether anterior or posterior. But the writer feels that they can, in a great many cases, be reduced progressively as an esthetic measure.

THE LATERAL BITES.—Referring back to Fig. 20, it was stated, in connection with the shape of the lingual surfaces of the teeth, that they were ground to permit of good contact during the lateral bites. This cannot be emphasized too much. Balance during these mandibular excursions must exist or trouble will be experienced.



FIG. 30

DENTURE SPACE.—The establishment of this measurement is often a difficult step for the operator. Ordinarily, his mind is on esthetics as he makes his plane approximately parallel with the imaginary line from nose to ear, decides upon the proper distance of the plane below the lip in repose and then trims the lower block until the profile is correct.

But there are involved mechanical difficulties along the way that the tooth block will aid in eliminating. For instance, as already described, the height of both bite blocks can be quite accurately established by it. How reassuring the block is in certain cases is well exemplified by Fig. 30.

The crest of the ridge is on a level with the dark lines on the labial surfaces of the two centrals. Without the tooth block the operator would certainly have difficulty assuring

himself that the height of the upper bite block should be only from these lines to the incisal edges, a measurement of six millimetres. In addition, the patient showed considerable of the labial surfaces of these anteriors and objected to an attempt to make them longer.

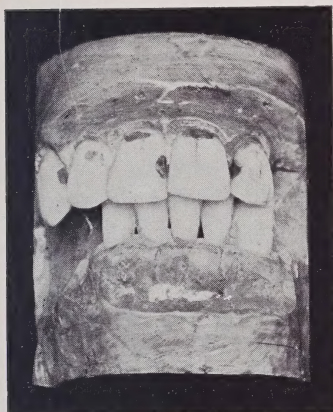


FIG. 31

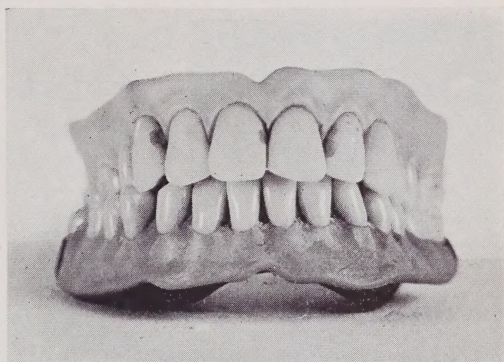


FIG. 32

As opposed to this small height measurement of the bite block in Fig. 30 is the situation as illustrated in Figs. 31 and 32.

Note the extreme size of the upper teeth. In this case, the patient again showed a great deal of the uppers because her lip was comparatively short. The writer suggested a smaller tooth, with no success. Without the tooth block there would have been difficulty, for patient and operator would certainly not have agreed readily on the location of the plane.

In Fig. 32 length of the lower teeth is greater than that of the natural teeth in Fig. 31. Again, this denture was photographed after having been rebased.

The same conditions apply to the lower bite block. Thus, in Fig. 10, as the lower block was trimmed in length to the distance between the incisal edge of a chosen upper tooth and the lower ridge, the possession of a tooth block was most encouraging.

Figs. 33 and 34 are examples of a case showing the opposite condition, a deep lower bite block. At first sight, there does not appear to be room for upper teeth of the size used. However, the patient's profile was quite convex, and the plane was established at pre-extraction height. In each of these cases, the operator could not know whether he was correct or not without the assistance of the tooth block.

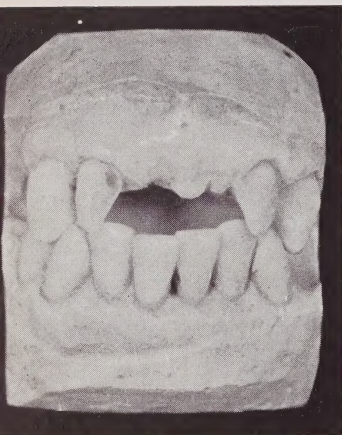


FIG. 33

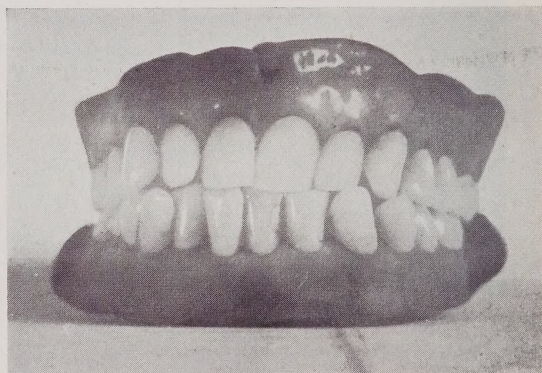


FIG. 34

ALVEOLECTOMY.—A case has already been cited, Fig. 27, where the patient avoided alveolectomy. It was considered good practice in some of these cases because the value of this surgical measure is being questioned by many.

But there is no intention on the part of the writer to argue that there are no sound applications of alveolectomy. Thus, in Fig. 35, trimming of the process reduced the abnormal condition on the right to the more or less normal one on the left. The young lady's profile was as illustrated in Fig. 36 after completion of the work.

Certainly such a case is quite beyond the range of facsimile reproduction.

THE BIOLOGICAL FACTOR.—An example was given where absorption increased the leverage on an upper denture and the anterior set-up was altered to lessen this tendency. Other examples might be drawn to attention, but, in general, it is felt that the tooth block lessens the probability of attendant troubles in many cases. For instance, by aiding in the correct location of the plane, outside of the esthetics of facial contour and expression, any functional disorders consequent upon an open or closed bite condition are avoided.

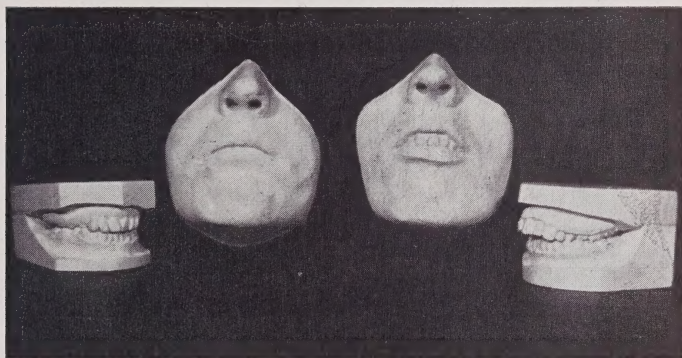


FIG. 35

THE PSYCHOLOGICAL FACTOR.—Often these tooth blocks are splendid for reassuring the patient. New dentures are sometimes like new shoes. They just do not seem right, and only when teeth of block and denture are measured is the patient convinced that conditions are the same as before extraction. In this role they are as valuable as the casts of the orthodontist.

PHONETICS.—Anterior teeth often play a considerable part in speech. If, now, artificial teeth can be placed in the patient's mouth in the same positions as those occupied by

the natural teeth, there should be less of a tendency to alter the speech of the patient. But when the dentist changes size, arrangement and level of the teeth there may be difficulty at once. One other element, the part of the denture covering the palate, may cause trouble, but that is rather outside the range of the article, and will not be discussed.



FIG. 36

SUMMARY

The problem of facsimile reproduction of natural anterior conditions has been taken up from the standpoints of esthetics, mechanics, biology, psychology and phonetics.

Here is a technique that, for the patient in the hands of the prosthetist prior to extraction, practically solves the problems of form, color, size and arrangement of the artificial teeth. By assuring correct inter-alveolar distance, it preserves proper facial length and contour and reduces to a minimum the lines tending to form about the mouth.

Mechanically, it accurately establishes the occlusal plane and aids the technician in the alteration of form, setting up and staining the teeth. The immediate denture technique secures the centric bite with certainty, and thereby eliminates one registration that is sometimes quite troublesome.

Biologically, psychologically and phonetically it was shown to have advantages.

But the writer attempted also to impartially point out its limitations and contra-indications and it is offered to the reader, not boastfully as a panacea, but in the hope that it may help in the search for more perfect esthetic results.

LIST OF REFERENCES

1. PROTHERO, James Harrison. *Prosthetic Dentistry*, pp. 355-381.
2. WILSON, George H. *The Dental Summary*, XXXII, 1912, pp. 867-877.
3. BERRY, F. H. *Annual Proceedings of the Institute of Dental Pedagogy*, Buffalo, 1903.
4. WILLIAMS, J. Leon. *The Dental Cosmos*, Jan., 1911.
5. KIRK, Edward C. *British Dental Journal*, XLIV, 1923, pp. 897-907.
6. ORTON, F. H. *Journal Nat. Dental Association*, VIII, 1921, pp. 691-703.
7. ORTON, F. H. *The Dental Digest*, XXV, 1919, pp. 321-341.
8. ASCHE, Thomas. *Dental Items of Interest*, LII, 1930, pp. 558-562.

9. ARATA, Mario F. The Dental Digest, XXVIII, 1922, pp. 431-439.
10. DAVIS, Lloyd. A Collection of Observations on a possible classification of the size, shade, color and arrangement of the anterior teeth for an edentulous mouth. Dental Faculty Library, 1931.
11. WHITE, S. S., Dental Mfg. Co. Catalogue—Porcelain and Accessories for Dental Ceramics, 1931.
12. COLUMBUS DENTAL MFG. CO. Booklet — Steele's Technic for the Application of Glaze and Stains.
13. ROACH, F. Ewing. Sectional Impression Technic. Booklet by Dee Co., Chicago, 1928.
14. SCOTT, T. N. Impressions for the Semi-dentulous Mouth, Faculty Library, 1930.

BIBLIOGRAPHY

ARATA, Mario F. Arrangement of Artificial Teeth According to Tooth Form and in Harmony with Facial Contour for Dentures and Bridges. *The Dental Digest*, XXVIII, 1922, pp. 431-439.

ASCHE, Thomas. The Economic Value of Esthetics. *Dental Items of Interest*, LII, 1930, pp. 558-562.

Discusses dentures from the standpoint of expectations of the patient, remuneration to the dentist, and enters a plea for more esthetic set-ups.

BERRY, F. H. Annual Proceedings of the Institute of Dental Pedagogics, Buffalo, 1903.

CAMPBELL, Dayton Dunbar. *Full Denture Prosthesis*, St. Louis, C. V. Mosby & Co., 1924, pp. 237-258.

A very general article.

CLAPP, George Wood. Increasing the Naturalness of Anterior Restorations. *The Dental Digest*, XXVII, 1921, pp. 661-5.

Discusses variation of hue in natural anteriors, the effect of increasing age, etc.

COLUMBUS DENTAL MFG. CO. Steele's Technic for Application of Glaze and Stains. Columbus, March, 1931.

DAVIS, Lloyd. A Collection of Observations on a Possible Classification of the Size, Shape, Color and Arrangement of the Anterior Teeth for an Edentulous Mouth. Faculty of Dentistry Library, 1931.

HARPER, Robert Newton. Esthetics in Full Denture Prosthesis. *Dental Items of Interest*, LII, 1930, pp. 397-400.

Short article on facsimile work.

HOUSE, M. M. Esthetics and Denture Construction. *Journal of the American Dental Association*, XIV, 1927, pp. 232-4.

Discusses typical arrangements, ridge forms. Gives a few general instructions re set-ups.

HOWARD, Jas. H. Esthetics as Applied to Full Denture Prosthesis. *Journal of the American Dental Association*, X, 1923, pp. 135-144.

Very good history of esthetics, etc.

KIRK, Edward C. The Problem of Artistic Harmony in Denture Prosthesis. *The British Dental Journal*, XLIV, 1923, pp. 897-907.

Very general article. Finally leaves problem to artistic perception of operator.

NELSON, A. Alfred. The Esthetic Triangle in the Arrangement of Teeth; Face Form, Tooth Form and Alignment Form, Harmonious or Grotesque. *Journal of the American Dental Association*, IX, 1922, pp. 392-401.

Description of arch forms, study of profiles, etc.

ORTON, F. H. Color of the Teeth. *The Dental Digest*, tistry. *Journal National Dental Association*, VIII, 1921, pp. 691-703.

Good description of status of technician, coloring of teeth, incongruity in esthetics situation followed by plea for manufacturers to help.

ORTON, F. H. Colore of the Teeth. *The Dental Digest*, XXV, 1919, pp. 321-341.

- PROTHERO, James Harrison. The Esthetics of Tooth Selection. *Prosthetic Dentistry*, Chicago, Medico-Dental Pub. Co., 1916, pp. 355-381.
- ROACH, F. Ewing. *Sectional Impression Technic*, Thos. J. Dee Co., Chicago, 1928.
- SEARS, Victor H. The Art Side of Denture Construction. *The Dental Digest*, XXIX, 1923, pp. 764-770.
- SCOTT, T. N. *Impressions for the Semi-dentulous Mouth*. Faculty of Dentistry, University of Toronto, 1930.
- TURNER, Charles R., ANTHONY, L. P. *American Textbook of Prosthetic Dentistry*, Philadelphia, Lea and Febiger, 1928, pp. 285-311.
- VEHE, W. D. Esthetics in Restorative Procedure. *Journal of the American Dental Association*, XV, 1928, pp. 1261-1270.
Discusses physics of color, etc.
- WEIR, Francis Scott. Practical Esthetics. *The Dental Digest*, XXX, 1924, pp. 253-262.
Classifies study of esthetics nicely.
- WHITE, S. S., Dental Mfg. Co. *Porcelain and Accessories for Dental Ceramics*, Philadelphia, Form 2405-E, 1931.
- WILLIAMS, J. Leon. The Esthetic and Anatomical Basis of Dental Prosthetics. *The Dental Cosmos*, Jan., 1911, p. 1.
- WILSON, George H. Esthetics of Dental Prosthesis. *The Dental Summary*, XXXII, 1912, pp. 867-877.

PERIAPICAL TISSUE CHANGES IN TEETH OF DOGS

following Various Methods of Pulp Removal
and the Use of Various Common Drugs



By

G. A. BUCHANAN, D.D.S.



A Thesis presented for the Degree of Bachelor of Science in Dentistry
Faculty of Dentistry, The University of Toronto, 1931



BULLETIN NUMBER EIGHTEEN

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

1933

PERIAPICAL TISSUE CHANGES IN TEETH OF DOGS

following Various Methods of Pulp Removal
and the Use of Various Common Drugs



By
G. A. BUCHANAN, D.D.S.

A Thesis presented for the Degree of Bachelor of Science in Dentistry
Faculty of Dentistry, The University of Toronto, 1931



BULLETIN NUMBER EIGHTEEN

ISSUED BY
THE CANADIAN DENTAL RESEARCH FOUNDATION
1933

Acknowledgments



The author wishes to take this opportunity to thank those men who so willingly assisted with this work.

To Dean Seccombe, Dr. A. E. Webster, and Dr. G. C. Cameron the writer is indebted for constructive criticisms and co-operative suggestions.

Professor O. Klotz and Dr. H. K. Box gave invaluable assistance in interpretation of microscopic slides, and the author is accordingly grateful.

Material assistance was rendered by the Banting Institute, whose staff so willingly co-operated in supplying material for the research experiments.

G. A. BUCHANAN

List of Illustrations

	Page
Radiograph Print of Young Dog's Tooth	15
Photomicrograph of Normal Apex. Young Dog	15
Photomicrograph of Apex. Old Dog	23
Print showing Old Dog's Tooth	16
Rubber Dam for Asepsis	17-18
Photomicrograph of Apex. Young Dog (arsenic treatment)..	21
Photomicrograph of Apex. Old Dog (arsenic treatment).....	23
Photomicrograph of Apex. Old Dog (arsenic, 4 days).....	25
Photomicrograph following Nerve Block	29
Photomicrograph following Infiltration	30
Photomicrograph following Cocaine Pressure	33
Photomicrograph following Campho-Phenique	36
Photomicrograph following Oil of Cloves	37
Photomicrograph following Phenol	38
Photomicrograph following Formo-Cresol	39
Photomicrograph following Sulphuric Acid	40
Photomicrograph following Silver Nitrate	41
Photomicrograph following Tincture of Iodine	42

Contents

	Page
Acknowledgments	3
List of Illustrations	5
Introduction	9
The Status of the Pulpless Tooth	11
Histological Study of Dogs' Teeth	15
Aseptic and Operative Technique	17
Devitalization by Arsenic Trioxide	19
Removal of Pulps by Use of Anaesthetics	28
Conduction Anaesthesia	28
Infiltration Anaesthesia	28
Pressure Anaesthesia	32
Drugs—	
Campho-Phenique	35
Oil of Cloves	36
Phenol	37
Formo-Cresol	38
Sulphuric Acid	40
Silver Nitrate	42
Tincture of Iodine	43
Summary	44
Conclusions	46
Bibliography	47

Introduction

THE health and function of a normal pulpless tooth are vitally connected with the physiological condition of the periapical tissues. Close attention should be centred on these tissues in order that they may be kept in a normal state or not damaged during reparative efforts. After pulp removal the vitality of the cementum is not necessarily altered, but it is possible that a number of failures in case management is due to damage of tissue by trauma or irritating drugs, leading to the denuding of cementum and then on to resorption.

The question is a most important one, and is closely connected with root canal therapy. This will be dealt with more fully in Chapter 1.

With a realization that a mental picture of the biological processes is of the greatest importance in root canal treatment, the object of this research is to study and evaluate the tissue changes in the periapical region following the various methods of pulp removal and the use of various common drugs.

Grove (1) in 1919 carried out some experiments in which he has shown the deleterious effect of certain drugs on these tissues.

Seigmund and Weber (2) in 1926; Euler and Meyer (3) in 1927; have experimented with arsenic in order to show its effect on the periapical region.

Since many difficulties present themselves in a study of this nature, one must resort to animal experimentation. However, this has some advantages, inasmuch as normal, non-infected teeth can be used and a strict technique of asepsis carried out. With proper control, we can be assured that any result shown will be due to the action of various drugs and mechanical procedure, without the complication of infection.

The Status of the Pulpless Tooth



THE question of the pulpless tooth is still one of the greatest problems facing the dental profession. There is still a great need for much intensive, scientific research, coupled with sound clinical observation and deduction. This problem is a very vital one, inasmuch as it deals with the health of the patient, and every effort should be put forth to further improve all phases of the subject, including a thorough diagnosis, operative procedure, therapeutics and technique of filling the canal. One must always keep in mind the relation of the tooth to focal infection.

On looking through the dental literature, one is impressed with the great number of contributions dealing with the pulpless tooth. There is, of course, a great variance of opinion and procedure, but there is also an earnest endeavour on the part of all to solve the various difficulties which make root-canal therapy so perplexing. It is perplexing, because so many factors must be considered. The health of the patient is paramount, and there is no doubt that apical infections may sometimes lead to grave systemic disturbances. Also, an apical area with a reduced resistance may be invaded by organisms from a remote part of the body, thereby setting up a secondary focus of infection. Focal infection is thus brought into the discussion, and is of vital importance. On the other hand, there is no doubt that a tooth, saved by a good root-canal filling, may, with safety, be retained in the natural denture. A healthy natural tooth is unequalled by any artificial substitute. We must think of aesthetics and the keeping of the masticatory machine in physiological function. How can we estimate the damage done to the digestive organs during the period, some years ago, when the profession was swept away in an orgy of extraction which led to the wholesale removal of all pulpless teeth, and even a number of vital ones. Following the scathing statements of Sir William Hunter concerning the shortcomings of dental operative procedure, the attention of the world was drawn to the serious

results which could follow an infection, retained in the mouth. Scientific proof followed, that infected periapical tissue could undoubtedly lead to serious consequences. The press took up the story, and soon there was a wide condemnation of the pulpless tooth. It became the fashion to lay the blame for every obscure ailment at the door of the pulpless tooth, notwithstanding the fact that many other portals of infection entry should also be taken into consideration. Thousands of teeth were extracted, and some rightly so, for marvellous recoveries from metastatic disease were reported. The literature contained numerous reports and proofs of recovery following the removal of infected teeth, which may or may not have shown any clinical signs of involvement. This is a very significant thing, and shows what care one must take in diagnosis and prognosis. But then we must take into consideration the fact that the public always hears of sensational cures, while attention is not always drawn to the many cases of treatment, which there unquestionably must be, of pulpless teeth serving a useful purpose, showing no sign of involvement, and being used by a person in sound health. There can be no doubt that there have been numerous examples of pulpless teeth which have been treated by conscientious and painstaking operators, that could be considered as good ethical practice. The future of teeth which are treated without thought of careful diagnosis, strict asepsis, and with no thought for surgical procedure, is questionable from the beginning. Nature has been very kind in most of the carelessly treated cases, and has done her best to compensate for the damage done. One by no means contends that an attempt to save all teeth should be contemplated. The prognosis of many cases is unfavourable from the beginning, and it would be folly to attempt treatment. Many teeth that had periapical involvement, accompanied by loss of membrane and cementum, were persistently treated although they had no chance of recovery. Again, many were treated with no consideration of the impaired health of the patient. Undoubtedly, extraction would have been the best procedure in these cases. The saner view of the members of the dental profession has been to protest the ruthless extraction of all teeth with pulp involvement, as they

believe that there was a place for root-canal therapy in certain cases. The above picture of widespread extraction corresponds to certain periods in the medical profession. The pendulum of treatment may swing from one extreme to another, but under scientific and careful reasoning, always returns to a more normal condition. And so through the efforts of many men the treatment of the pulpless tooth is being greatly improved and the subject is being treated in a more scientific way.

At the present time, a most important feature of the problem is a complete diagnosis of each individual case, with the present and future health of the patient a vital point of consideration. Medical and dental practitioners are co-operating in a number of cases, and the patient gets a much more valuable service. Patients who are suffering from serious systemic troubles are considered unfavourable for root-canal work. Patients who are below normal health and apparently have a lowered resistance make doubtful risks for treatment other than surgical. Local diagnosis also has an important place, and the condition of the tooth, together with the apical tissues, must be diagnosed carefully. Then comes the importance of a detailed technique for pulp removal and case management. Surgical asepsis is of great importance, as infection is the greatest factor in the consideration of success or failure. A knowledge of drugs and their action and effect on the tissues must be considered. Finally, a careful technique of root-canal filling is necessary.

The newer concepts in root-canal work lead to the stressing of the importance of the apical tissues. Many operators are prone to overlook the great damage that can be done to the periodontal membrane and cementum by mechanical trauma and the use of irritating drugs. Valuable work has been done by a number of men in stressing the importance of keeping these tissues in a physiological state. On the periodontal membrane and cementum rests the onus of keeping a pulpless tooth in a state of health and service. If these tissues are destroyed from any cause, the tooth veritably becomes a foreign body, and nature attempts to remove it.

Grieves (4) has made a very thorough survey of dental literature containing evidence only, and reports: "The pulp has no part in the closing of the canal. This is the function of the cementoblasts, which are found between the fibres of the pericementum next to the root end, and where it dips down into the canal." Such authorities as Davis, Box, Thoma, Grove, Hopewell-Smith and Hatton state: "That provided the pulp has been removed without traumatic, bacterial, or chemical injury of the periapical tissues, nature will continue the deposition of cementum until, in some cases at least, the apical foramen is completely closed."

Rational root-canal technique must be planned so that the natural reparative forces will be encouraged. Pulpless teeth can be unequivocally declared to be healthy only when they have vital apices and normal tissues."

Blayney (6) maintains that: "The primary issue is a determination, not of the methods of treating infected roots, but of how to remove a vital pulp and maintain a healthy periapical tissue."

Webster (7) urges that more thought be given to the physiological and pathological state of the tooth itself and its surrounding tissues, and warns the profession of the deleterious effects of foreign bodies, and certain drugs being forced through the apices.

The unanimous opinion of clinicians and pathologists has led to the appreciation of the importance of the periapical tissues to the welfare of the pulpless tooth.



HISTOLOGICAL STUDY OF DOGS' TEETH

A histological study of dogs' teeth and surrounding tissues is of interest at this time. The permanent teeth of a young dog which were examined show the dentine to be very thin in comparison to the width of the teeth, forming very large pulp canals (Figs 1 and 2). The apex of the cuspid is widely open (Fig. 8) and entered by groups of large vessels which provide an abundant blood supply for the pulp. The cementum of the pre-molars and molars of the same animal shows a more active process, and at the apices, secondary cementum



FIG. 1. RADIOGRAPH PRINT OF UPPER PERMANENT CUSPID OF YOUNG DOG.

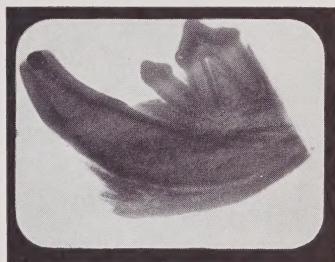


FIG. 2. RADIOGRAPH PRINT OF LOWER PERMANENT CUSPID OF YOUNG DOG.



FIG. 3. PHOTOMICROGRAPH OF APICAL REGION OF PRE-MOLAR OF YOUNG DOG. CEMENTUM IS BEING LAID DOWN AT APEX.
(Mag. 80)

is being laid down around the vessels entering the foramen, thus forming many accessory canals (Fig. 3). The vessels of the pulp are very large, and contain an abundant supply of red blood cells. From a human point of view one would almost say that a hyperemia were present.

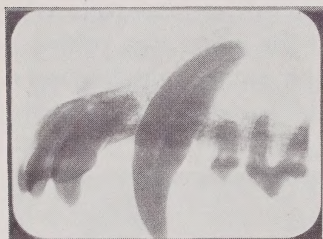


FIG. 4. RADIOGRAPH PRINT
SHOWING UPPER CUSPID OF
OLD DOG.



FIG. 5. RADIOGRAPH PRINT
SHOWING LOWER CUSPID OF
OLD DOG.

In the case of older dogs we find the dentine has been built up to such a degree that the pulp canal has been reduced very considerably in size (Figs 4 and 5).

Many layers of cementum have been laid down at the apex, resulting in numerous foramina from which accessory canals lead into the pulp (Fig. 9). The alveolar process is very dense, especially in the lower jaw.

Because of these observations, older dogs were chosen for the cases to follow, as the teeth of these animals, compared to those of the younger dogs, would more closely approximate conditions found in the teeth of mature patients.



ASEPTIC AND OPERATIVE TECHNIQUE

A general anaesthetic was used in all cases, consisting of sodium amytal (sodium iso-amyl-ethyl barbiturate) given intravenously in doses of 3 to 5 cc's for each dog. This proved to be very satisfactory, as it induced deep anaesthesia for periods of two to three hours. Muscles were relaxed and

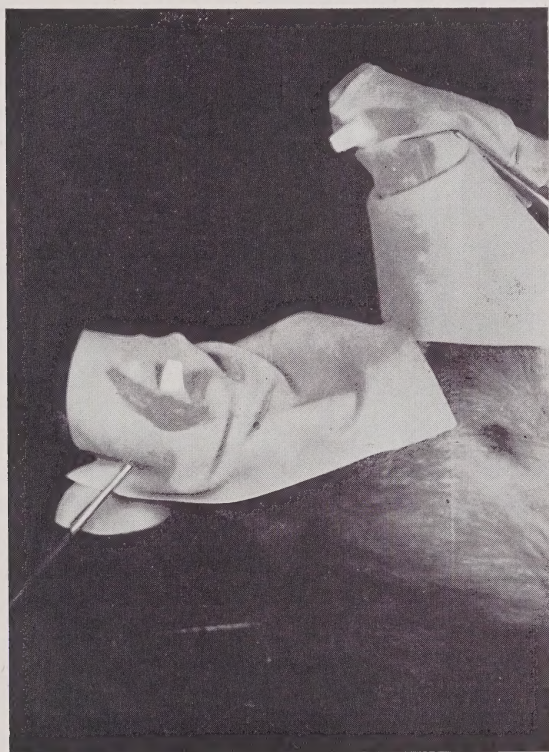


FIG. 6. RUBBER DAM IN PLACE

the jaws were easily held wide open to permit ease of operation. The mouth was clear of saliva under the anaesthetic. To ensure an aseptic field a rubber dam was used in all cuspid operations (Figs. 6 and 7).

The field of operation was swabbed with pure phenol, followed by 65% alcohol, at the commencement of the operation, and repeated frequently during the cavity preparation.

All hand instruments were placed in boiling water for fifteen minutes before use. Discs, stones and broaches were kept in pure phenol, and before use were washed in alcohol.

In each case, access to tooth was gained by cutting off a portion of the cusp with a disc or stone (Fig. 6). Access to the pulp was gained by the use of a small bur followed by one of the larger size to enlarge the cavity.



FIG. 7. RUBBER DAM AND MOUTH PROP IN PLACE

In the arsenic cases, arsenic trioxide of a known quantity was placed on the exposed pulp and a mix of crown and bridge cement was poured into the cavity to ensure a non-permeable seal, care being taken to cause no pressure on the dressing (Figs. 2 and 5).

At the conclusion of each case, the dog was killed with ether, the upper and lower jaw sectioned and immediately placed in a fixing solution. Radiographs were taken as a check on the size of the canals. From these we can say that the pulps in all cases were approximately the same size and the apices of the same development, with the exception of the first dog, which we purposely used to show a result from a tooth with a wide open apex. The radiographs also assisted in blocking out the required teeth with the desired amount of bone surrounding them. The blocks were then decalcified and treated by the celloidin method. The sections were cut fifteen microns thick and stained with haemotoxylin and eosin.

DEVITALIZATION BY ARSENIC TRIOXIDE

Arsenic was used for devitalization of the dental pulp by Wood in 1833. In 1836 Spooner recommended it for this use in the form of arsenic trioxide, and it enjoyed an extensive use for many years, with apparent success. Of late it has come into considerable disrepute because of its denunciation by a number of men in the profession. The dental literature is replete with articles containing condemnation of its use. Many men make the statement that if used it will make its escape through the apical foramen in all cases, and will work havoc on the periapical tissues, and will be followed by necrosis of tissue cells in that region. There was a period when all failures of root-canal therapy were attributed to this powerful drug. Others are more conservative, and condemn its use because of the dangers involved and the fear of its periapical action. On the other hand, a few men still champion its use, and claim that, with careful precautions, it still has its place in the dental office.

Most of the text books (8, 9, 10, 11 and 12) carry a description and technique of its use, but always state that the quantity used, also the length of application, should be carefully gauged. Davis (13), on the other hand, condemns its use. He is very emphatic in saying that it has no place in the dental office (14). McGehee (15) does not include arsenic in his text.

Garvin (16), by the careful charting of clinical evidence

over a period of thirteen years, found that the percentage of success in arsenic treatment was equal to that where cocaine had been used. From his clinical tabulations he states: "We can find nothing to convince us in the cases thus examined that with proper technique it is wrong to ever use arsenic in the treatment of teeth."

Scientific proof for the discarding of arsenic when it is used in a careful and methodical way seems to be lacking. It is a problem which presents many difficulties.

Arkovy (17), Weber (18), Box (19), and others have noted the changes in the pulp due to arsenic.

Heinze (20) claims that arsenic can be found at the apex at the end of two days. After a longer period he claims arsenic is found in the rest of the tissues. Others, however, do not agree.

Siegmund and Weber (21) have shown that arsenic left in a tooth for five days produces in the periodontium an acute periodontitis with all accompaniments. If left for a longer time they report a more marked result, leading to a heavy inflammation of a greater or lesser part of the tissue.

Euler and Meyer (22) have shown a resulting inflammation after the sealing of arsenic for eight days. One interesting result they have shown is the picture after the sealing of arsenic trioxide in a tooth for an extended period of time (28 days). They report that the inflammation had dwindled. There was still a slight cell infiltration remote from the apex. The reduction in inflammation had evidently made a more favourable field, and shows a loose fibrillar connective tissue laid down around the apex. Their results with colloidal arsenic, however, were more violent.

In the following experiments arsenic was placed in contact with an exposed pulp for periods ranging between one and four days.

Prior to the killing of the dog, it was noticed that the crowns of all treated teeth had undergone definite colour changes. The crowns of the teeth in which arsenic had been sealed for four days were a slaty black colour, and those of the three-day period were only slightly lighter in shade. The teeth of the two- and one-day period were a dark gray.

It is said that the complete death of pulp results in a change of colour to the tooth, as above (23).

CASE No. 1

An arsenic paste of a popular brand was used. No given strength was printed on the wrapper and no definite amount of arsenic could be measured out. An amount of the paste about the size of a pin head was used.



FIG. 8. PERIAPICAL AREA OF CUSPID OF YOUNG DOG. LARGE OPEN APEX. ARSENIC TRIOXIDE SEALED IN TOOTH FOR 4 DAYS (Mag. 80)

The dog was a young animal, the teeth of which had large pulp canals and wide open apices.

Fig. 8 shows the result of the arsenic paste being sealed in the tooth for four days. There is a picture of subacute pericementitis with bone involvement. In the membrane near the apex we have inflammation and a marked dilatation of the blood vessels. A number of plasma cells are present. There is a little granulation tissue forming in the margin of the alveolar bone. A number of fusiform cells are seen near the blood vessels. In the alveolar area are a few polymorphonuclear leucocytes. A large number of plasma cells and a few endothelial cells are present, together with a few giant cells also osteoclasts, showing some bone absorption. The alveolar bone area could almost be considered an osteitis. The most interesting thing about the picture is the greater involvement of the area around the bone as compared with the periodontal membrane, and a zone between the membrane and the pulp that is almost clear of inflammation, in fact almost appearing normal. There is no evidence of necrosis.

Tooth treated with arsenic for three days

The picture in this case is very similar to the previous one, only very slightly less marked.

Tooth treated with arsenic for two days

We note the extreme dilatation of the blood vessels in the region of the shaft. Plasma cells are arranged between the nerves in the shaft, also an odd polymorphonuclear leucocytes. Inflammation is marked, but of a lesser degree than in both preceding cases. Scattered haemorrhagic areas appear, a little hemorrhage here and there. The characteristic in this picture is the infiltration by plasma cells. There is not the reaction on the border of the bone as in the former cases. This is an acute inflammation, and as before, the reaction is more marked in the shaft area.

Tooth treated with arsenic for one day

Here we have a change that is not so severe, although it is a picture of acute inflammation that is more marked in the

area of the bone than in the membrane, except in the region of the membrane bordering the alveolar process. In the pulp near the apex we have the vessels engorged with blood, and white cells situated along the border. The cells in some of the vessels have no definition—they appear to be almost liquefied.



FIG. 9. APICAL REGION OF CUSPID OF OLD DOG. ARSENIC 1/20TH GRAIN SEALED IN TOOTH FOR FOUR DAYS (Mag. 80)

CASE NO. 2

In this case an arsenic paste was made up in order that we could measure definite quantities for use.

Arsenii Trioxidii (99% pure)	z i
Cocainae Hydrochloridi	gr.x
Thymol	gr.v
Alboline	q.s.

Misce fiat pasta

The first three ingredients were first mixed together and spatulated thoroughly, to be reasonably sure that the arsenic was spread throughout the whole mass. $\frac{1}{4}$ grain of this mixture was carefully measured out and spread out on a glass slab in a thin layer. This was divided into five parts, thereby making $\frac{1}{20}$ th gr. of arsenic to each part. When ready for use, a slight amount of alboline was added to each part to make a paste.

An old dog was chosen for this experiment because of the development in the apices of teeth of more mature animals. $\frac{1}{20}$ th of a grain of arsenic was applied in each case.

Tooth treated with 1/20th grain arsenic for four days

In Fig. 9 we find the result when $\frac{1}{20}$ th grain of arsenic was left in a tooth for four days. The periapical tissue in this case shows a very slight amount of subacute inflammation. There appears to be no disturbance in the bone; plasma cells predominate. A few cells are found in the shaft. The inflammation in the periodontal membrane is evenly distributed, unlike the case in the younger dog, where there was a clear space of normal-appearing tissues directly at the apex. The effects appear to be very local.

The cases where arsenic was left in the tooth for three, two days and one day respectively show much the same picture as the above, with lesser degrees of involvement.

Pre-molars treated with arsenic for various periods

For the pre-molars, $\frac{1}{60}$ th of a grain of arsenic was used on various teeth in periods of one to four days.

Tooth treated with 1/60th grain arsenic for four days

Fig. 10 shows a condition of abscess formation. The membrane is destroyed around the apex, and this necrosed

area extends up the side of the tooth for some distance. Large numbers of polymorphonuclear leucocytes are present. The pulp is thoroughly degenerated, and shows evidence of fibrosis.



FIG. 10. 1/60TH GR. ARSENIC—TIME, 4 DAYS

Tooth treated with 1/60th grain arsenic for two days

This picture shows a cellular reaction near the bone, but it diminishes as the membrane is reached. The inflammation is not very marked.

Tooth treated with 1/60th grain arsenic for one day

A very mild infiltration of cells took place, reaction very slight, almost normal (Fig. 12).

NOTE.—With reference to Fig. 10: It is doubtful if the abscess was caused by the action of the arsenic only, for the following reasons. Twenty-four hours after the arsenic was first applied to the tooth it was noticed that the tooth had



FIG. 11. 1/60TH GR. ARSENIC—TIME, 2 DAYS

exfoliated slightly from its socket and had become loosened. This condition progressed, and at the end of the four days had reached the condition seen in Fig. 10. The teeth which are represented by Figs. 11 and 12 do not show any signs of a condition which might lead to a violent reaction in one day. Neither did they show any clinical evidence at the end of the one-day period as was noticed in the case of the tooth shown in Fig. 10.



FIG. 12. 1/60TH GR. ARSENIC—TIME, 1 DAY

REMOVAL OF PULPS BY USE OF ANAESTHETICS

The profession as a whole is agreed that the most ideal method of pulp removal is by the use of conduction and infiltration anaesthesia. The anaesthetic solution is tolerated very well by the tissues, and its action apparently has no damaging effects.

Conduction Anaesthesia

An injection of novocaine was made at the mental foramen and the pulp of the lower cuspid removed. There was a profuse hemorrhage, and this was stopped by the use of dry aseptic points and the canal dried out by an application of alcohol followed by air from a chip blower. A dressing of campho-phenique was then placed in the canal and the tooth sealed with cement. We can thus estimate the amount of reaction to the mechanical injury, and use the knowledge for a comparison with further results when more than one factor enters the question. Following nerve block, the dog was left alive for 48 hours.

Fig. 13 shows the result of the removal of a pulp following a nerve block. There is a little hemorrhage around the apex. There is also some inflammation around the periapical region, but not sufficient to extend any distance; it is very slight. This slight reaction is fairly local.

Infiltration

Infiltration anaesthesia, like conduction anaesthesia, is considered as an ideal method for pulp removal. Some writers call attention to the fact that owing to the blood vessels in the apical region contracting from the action of the adrenalin, there may be very little hemorrhage when the pulp is removed. If the canal be filled immediately, or a tight, wet dressing be inserted, and a hemorrhage occurred at the apex when the adrenalin has been taken from the part, the blood would have no outlet and a mild pericementitis could possibly result.

CASE 1

Two cc's of novocaine solution were injected into the soft tissues and against the alveolar process, just above the level of the apex of an upper cuspid. The pulp was exposed with burs, and a large opening made into the pulp chamber to permit

easy access. A broach was inserted into the canal and down to the apex. The pulp was removed, but no hemorrhage resulted. By means of various sized broaches every effort was made to thoroughly clean out the canal. The canal was then flooded with sterile water and a wet paper point was packed tightly into place. This dressing was allowed to remain in place for forty-eight hours, and the dog was then killed.



FIG. 13

Fig. 14 is a photomicrograph of the condition below the apex after treatment. There is a subacute inflammation which involves the channels surrounding the bone.

The picture in this case is about the same as when 1/20th grain of arsenic had been left in an older dog's tooth for periods of two and three days. There is a little hemorrhage showing in the beginning of the canal.



FIG. 14. PHOTOMICROGRAPH OF APEX FOLLOWING INFILTRATION TECHNIQUE

CASE 2

The technique in this case was the same, except that a dry paper point was placed in the canal in order to absorb any blood that might result from a hemorrhage taking place after the effect of the adrenalin had worn off.

Fig. 15 shows the result. There is a little hemorrhage around the apex. Some inflammation of a slight degree is found in the periapical tissues, but is not sufficient to extend to the bone. The reaction is fairly local.



FIG. 15. PHOTOMICROGRAPH OF APEX FOLLOWING INFILTRATION
TECHNIQUE

PRESSURE ANAESTHESIA

Pressure anaesthesia using cocaine crystals is a very popular method of technique in pulp removal. The crystals are placed in contact with the bleeding pulp, a small piece of unvulcanized rubber is placed in the cavity and pressure brought to bear on it to force the cocaine through the pulp tissues. Clinicians point out that one must be careful not to use this method in infected cases for fear of forcing any bacteria through the apex. Some warn against the use of too much of the cocaine because of the probability of periapical damage due to the fact of cocaine being a protoplasmic poison. Then there are the precautions one must take in gauging the amount to be used because of the toxic effects which may result.

CASE 1

The pulp of a lower cuspid was exposed and the cavity opened freely. About one-half grain of cocaine was placed in cotton and then placed over the pulp. Unvulcanized rubber was then placed in the cavity and a pressure exerted by means of a blunt instrument. The cavity was box-like in shape and about one-quarter of an inch in depth, so the pressure was exerted directly against the pulp. This procedure was repeated with another quantity of cocaine on two more occasions. The rubber and cotton were then removed and the tooth sealed with cement. Forty-eight hours afterwards the dog was killed.

Fig. 16 shows the result. The periapical tissues look in normal condition. No inflammatory reactions. There was no damage to the pulp tissue near the apex.

CASE 2

The technique in this case was the same as in Case 1, with the exception that two drops of staphylococcus and streptococcus culture were placed in the cavity over the pulp before applying the cocaine and pressure. The staph. and strep. had been cultured in a broth for forty-eight hours prior to the operation.

Fig. 17 shows the slight inflammatory reaction, which is of a slight nature. This inflammation is located around the vessel within the pulp and to a slight degree without the apex.

The vessels of the pulp are remarkably free from evidence of pyogenic response, and there is no suggestion of a response to infection of strep. and staph. in the periapical region.

CASE 3

A second experiment with technique as in Case 1 was repeated and the dog killed twenty-four hours after the operation.

Result—no reaction. Tissues normal.



FIG. 16. PHOTOMICROGRAPH OF PERIAPICAL TISSUES FOLLOWING COCAINE PRESSURE

CASE 4

Case 2 is repeated here, but the dog was killed twenty-four hours after operation.

The result showed a little hemorrhage in the canal, but it was due to rupture of blood vessels in the mechanical removal of the pulp. No inflammatory reaction was shown, but there was a slight reaction. In the periapical tissue a few leucocytes were present. There is a slight congestion of vessels.



FIG. 17. APICAL REGION AFTER PRESSURE ANAESTHESIA, USING INFECTED COCAINE

DRUGS

Attention has been drawn on numerous occasions to the damaging effects of certain drugs on the periapical tissues. As previously stated, infection plays an important role in failures connected with root-canal treatment. The object of therapeutics in pulpless tooth treatment is to destroy any organisms that may be present and to sterilize the dentine, without causing any damage to the periapical tissues. One is apt, while concentrating all attention on the important question of infection, to forget the destroying effect of certain drugs on normal vital tissue. The attention of the profession had been called on numerous occasions to the ill effects of certain of these drugs if allowed to escape through the tooth apex.

In the following experiments the pulp was removed from various teeth. The hemorrhage was stopped and the canals thoroughly dried out. The teeth were then treated with various drugs. In each case, care was taken not to force the drug through the apex. The teeth were then sealed with cement and the dressing allowed to remain for measured lengths of time.

CASE 1

R	<i>Campho-Phenique</i>	
Camphor		40 parts
Mineral Oil		40 parts
Phenol		20 parts

Two drops of Campho-Phenique were placed in the pulp chamber and gently teased down the canal to the apex. This was followed by a paper point that had been soaked in the drug. The dressing was allowed to remain in the canal for twenty-four hours.

In Fig. 18 we see the result of this treatment. There is a little pulp tissue remaining in the canal, but it is still normal. There is no inflammatory reaction. The vascular channels are quite clear. In the periapical region there is a very slight inflammatory response, as in the case of the pulp removal by nerve block. A few inflammatory cells are shown, together with some dilatation of the blood vessels.

CASE 2

Oil of Cloves

The above experiment was repeated, but Oil of Cloves was used in place of the Campho-Phenique. The dressing was left in place for forty-eight hours.

Fig. 19 shows the reaction of the tissues due to Oil of Cloves. There is a little hémorrhage in the canal. The blood is converted into pigment masses. No inflammatory



FIG. 18. ROOT-CANAL TREATED WITH CAMPHO-PHENIQUE

reaction is seen in the pulp remnants, but there are a few reactionary cells in the periodontal membrane.

Phenol (pure)

In this case the pulp of a lower cuspid was removed and the canal dried out. Two drops of Phenol were placed in the canal and teased down to the apex. This was repeated a second time. A paper point dipped in Phenol was placed into the canal and the tooth sealed with cement. The dressing was left for twenty-four hours.



FIG. 19. ROOT-CANAL TREATED WITH OIL OF CLOVES

Fig. 20.—The reaction to Phenol is very slight above the apex. It was localized and probably due to mechanical trauma from pulp removal.

CASE 4

R	<i>Formo-Cresol</i>	
Formaldehyde		50 parts
Tri-Cresol		50 parts

The Formo-Cresol was procured from the Dental Infirmary, University of Toronto.



FIG. 20. ROOT-CANAL TREATED WITH PHENOL

The same technique as in the previous cases was carried out, with the exception that Formo-Cresol was used as the drug, and the dressing was left in place for forty-eight hours.

Fig. 21.—There is evidence of operative hemorrhage in the canal, also bits of pulp debris. In the periodontal membrane we find a low grade inflammatory reaction, not acute.



FIG. 21. ROOT-CANAL TREATED WITH FORMO-CRESOL

CASE 5

Sulphuric Acid (50%)

Following pulp removal the canal was dried out and a drop of Sulphuric Acid placed within. Broaches of different sizes were inserted to the apex and withdrawn with a scraping motion. Files were used in an attempt to enlarge the canal. Care was taken not to force any acid through the apex. This was followed by a solution of Sodium Bicarbonate to neutralize the acid. An effervescence resulted. The canal was then



FIG. 22. CHANGES TO PERIAPICAL TISSUES FOLLOWING USE OF H_2SO_4

dried carefully with paper points and a dressing of Campho-Phenique was inserted and left for forty-eight hours.

Fig. 22 shows the result of a case carried out by Callahan's method. There are evidences of cotton in the canal near the apex, probably retained because of the roughened surface due to the enlarging of the canal. There is also some debris of pulp tissue. The periapical vessels are dilated and congested. A very sharp inflammatory reaction is present. This is not

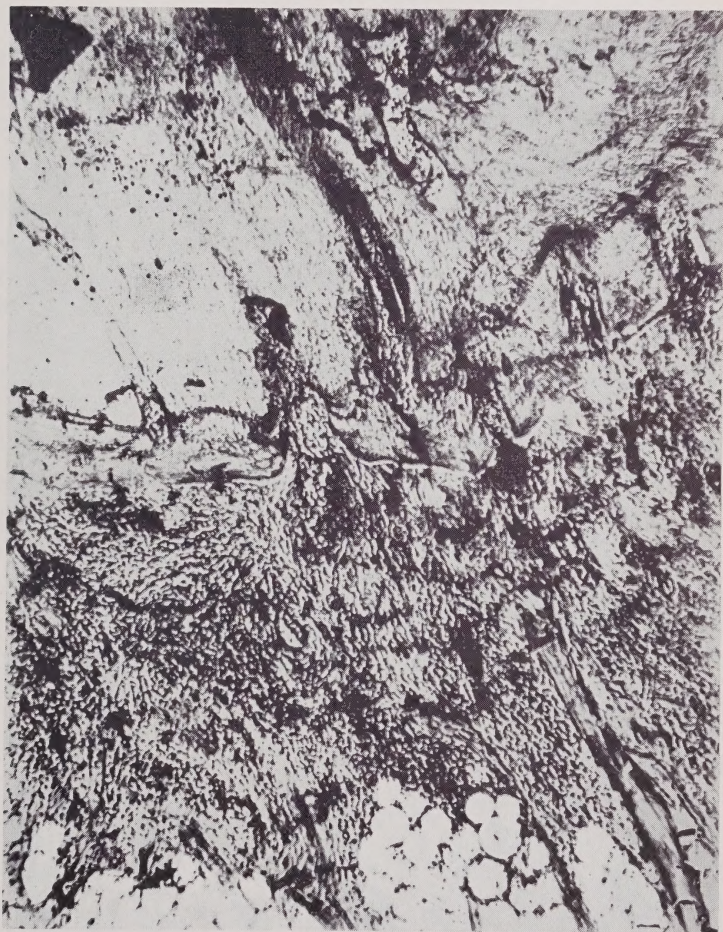


FIG. 23. PRECIPITATED SILVER NITRATE TREATMENT

so intense in the bone area. There are a striking number of Eosinophiles present.

CASE 6

Ammoniacal Silver Nitrate

A drop of Ammoniacal Silver Nitrate was teased down the canal and immediately followed by Oil of Cloves to precipitate the Silver. This was repeated in the case of the Clove Oil two or three times. A dressing of Campho-Phenique was inserted and allowed to remain for forty-eight hours.



FIG. 24. TINCTURE OF IODINE TREATMENT

Fig. 23.—The canal near the apex shows the presence of pigmented material. The small vessels entering the canal are thrombosed. A very marked inflammatory reaction is noticed in the soft tissues of the periapical region, and of more intense nature than in any of the preceding cases. The reaction is particularly marked around the vessels, but not so intense in the bone.

CASE 7

Tincture of Iodine (5%)

In this case two drops of Iodine Tincture were placed in the canal and carried toward the apex. A dressing of Campho-Phenique was inserted and allowed to remain for twenty-four hours.

Fig. 24.—This shows an intense inflammation around the apex which usually appears in a case of suppuration. A destruction of some of the periodontal tissues is suggested. A great number of polymorphonuclear leucocytes are present. The infiltration also involves the neighbouring bone. The appearance is almost that of a small acute abscess at the apex, and looks as if the drug itself played a part in bringing about the intense reaction.



SUMMARY

Arsenic

In the preceding experiments, two types of teeth were used: one, with a wide open apex, and the other type with an apex closed in with layers of cementum and containing many small accessory canals.

Arsenic trioxide, when used on the exposed pulp of the first type of tooth, produced marked changes in the periodontal membrane and the bone. These inflammatory reactions in the area of the bone were more intense than in the membrane, and an area of tissue immediately at the apex was little affected. Treatments applied one and two days respectively produced approximately the same reactions, i.e., subacute inflammatory conditions, more in the bone than membrane. Treatments applied for three- and four-day periods produced an osteitis in the bone with lesser reaction in the membrane.

In cases with a more developed apex, arsenic for one-, two-, three- and four-day periods produced a slight inflammatory reaction, which appeared to be a secondary result from some irritation.

The picture of subacute inflammation was more evenly distributed than was the case with an undeveloped apex, and showed no bone involvement. The small area of normal tissue directly at the apex was also missing, and the slight amount of inflammation was evenly distributed in the membrane.

A pre-molar tooth in which 1/60 gr. arsenic was sealed for four days showed a picture of abscess formation and destruction of the membrane, but we are of the opinion that the pulp had become degenerated prior to the application of arsenic (p. 26). Other experiments on pre-molar teeth produced a very slight inflammation.

Anaesthetics in Pulp Removal (Developed Apex)

Pulp extirpation following a nerve block produced a very slight inflammation in the periapical tissues, and was fairly local. We can conclude that this reaction was due to mechanical trauma of pulp removal.

Infiltration

Infiltration anaesthesia produced no hemorrhage after pulp extirpation.

Following a wet dressing tightly packed in the canal, a subacute inflammation resulted in the periodontal membrane and also involved the surrounding bone. The same technique, only with a dry dressing in place of the wet one, produced a more local inflammation of a lesser degree which did not extend to the bone.

Pressure Anaesthesia

Pressure anaesthesia with cocaine produced no reaction in the periapical tissues. Here we must take into consideration the fact that the pulp was not removed, so a result similar to the nerve block experiment would not be expected. The object of the experiment was to show the action of cocaine only on the tissues.

Pressure anaesthesia with infected cocaine produced a slight leucocytic infiltration, but the tissues were remarkably free from any pyogenic response. We must take into consideration the resistance of a dog to certain bacteria, and also that the infection was forced from some distance to the apex.

Drugs (Developed Apex)

Treatment of the canal with campho-phenique produced no inflammation due to the treatment of the drug.

Oil of cloves produced no inflammatory changes.

Phenol produced a very slight reaction in the periapical tissues.

Following a treatment of formo-cresol in the canal, a light inflammation was produced in the periodontal membrane. This reaction was not acute.

Enlargement of the canal, using sulphuric acid, produced a sharp inflammatory reaction in the periapical tissues, but not of such intensity in the bone.

Precipitated silver nitrate produced a more marked inflammation than any of the preceding drugs. The reaction was particularly marked around the vessels, but not so intense in the bone.

Following the treatment of a canal with tincture of iodine, an intense inflammation occurred in the membrane, which suggested tissue destruction and suppuration. The inflammation also involved the neighbouring bone.

CONCLUSIONS

Pulp Removal Technique

From the preceding experiments, nerve block, infiltration and pressure anaesthesia appear to be ideal, with reference to the effects these methods have on the periapical tissues.

Arsenic used in teeth with undeveloped apices affects the bone and shaft to a greater degree than the periodontal membrane. For periods greater than two days we get a rarifying osteitis. Therefore, arsenic should be used in young teeth for no more than twenty-four hours, if at all, and care be taken not to leave it for longer periods.

Arsenic used in the experiments with fully developed teeth caused no effects within four days which would lead us to condemn its use.

All the results obtained from the various methods of pulp removal lead us to believe that had the cases been carried on with mild antiseptic dressings, complete repair would have taken place in the periapical tissues.

Drugs

Oil of Cloves and Campho-phenique are ideal drugs with respect to effects on the periapical tissues.

Phenol proved to be less damaging than is claimed by some clinicians. It is self-limiting.

Formo-cresol produced a very mild inflammation. This may have been due to evaporation of the formaldehyde of the solution before use. Since a solution of this kind does not produce damage to the periapical tissues, its antiseptic and germicidal qualities should be tested.

Sulphuric acid should be used with great care, as it is possible to cause an intense reaction with this method.

Silver nitrate also produces an intense inflammation, and it should be used very carefully.

From our results with 5% tincture of iodine, we conclude that it can be a dangerous drug for root canal treatment. If used, it should be used in weak solutions and with great care.

Bibliography

1. Grove, C. J. Some Causes for Periapical Infections. with the Pathology; Journal of A.D.A., 1919, p. 669.
2. Siegmund, H., and Weber, R. Pathologische Histologie der Mundhöhle; Verlag von S. Hirzel, 1926, p. 270.
3. Euler, H., and Meyer, W. Pathohistologie der Zähne; J. F. Bergmann, 1927, p. 284.
4. Grieves, C. J. A Review of the Clinical Data Relative to Efficiency of Various Root-Filling Methods; Journal of the N.D.A., 1919. p. 126.
5. Crane, A. B. The Dental Cosmos; 1926, p. 710.
6. Blayney, J. R. Some Factors in Root Canal Treatment; Journal A.D.A., 1924, p. 840.
7. Editorial Dominion Dental Journal, 1917, p. 61.
8. Prinz, H. Dental Materia Medica and Therapeutics; C. V. Mosby Co., 1926, p. 251.
9. Ward, M. I. American Text Book of Operative Dentistry; Sixth Edition; Lea and Febiger, p. 567.
10. Marshall, J. S. Principles and Practice of Operative Dentistry; Fifth Edition; J. B. Lippincott Co., p. 480.
11. Johnson, C. N. (J. P. Buckley) A Text Book of Operative Dentistry; Fourth Edition; P. Blakiston's Son & Co., p. 312.
12. Black, G. V. Operative Dentistry; Fourth Edition; Medico-Dental Pub. Co., Chicago. p. 384.
13. Davis, W. C. Essentials of Operative Dentistry; Fourth Edition; C. V. Mosby & Co., p. 248.
14. Davis, W. C. Dental Items of Interest; 1923, p. 413.
15. McGehee, W. H. O. Text Book of Operative Dentistry; P. Blakiston's Son & Co., 1930.
16. Garvin, M. M. Journal of the N.D.A.; 1919, p. 195.
17. Arkovy, J. Experiments on the Action of Some Agents used for the Devitalization of the Tooth Pulp—Transactions of the International Congress; Vol. 3; 1881, J. W. Kolckman, pp. 488-498.

18. Siegmund, H., and Weber, R. Pathologische Histologie der Mundhohle; Verlag von S. Hirzel, 1926, p. 270.
19. Box, H. K. Histological and Pathological Studies of the Dental Pulp; Bulletin 3 and 4; Canadian Dental Research Foundation, 1922. p. 46.
20. Heinze Quoted by Siegmund and Weber, Pathologische Histologie der Mundhohle; p. 272.
21. Siegmund, H., and Weber, R. As above. p. 273.
22. Euler, H., and Meyer, W. Pathohistologie der Zahne; J. F. Bergmann. 1927, p. 284.
23. Ward, M. I. (Coolidge, E. D.) American Text Book of Operative Dentistry, p. 609.

Additional References

- | | |
|-------------------|---|
| Editorial | Dominion Dental Journal; 1917, p. 61. |
| Crane, A. B. | The Dental Cosmos; 1926, p. 709. |
| Crane, A. B. | Feasibility of Root-Canal Treatment; Journal A.D.A., 1924, p. 610. |
| Coolidge, E. D. | Discussion of "Feasibility of Root-Canal Treatment," Journal A.D.A., 1924, p. 615. |
| Coolidge, E. D. | American Text Book of Operative Dentistry (Ward); Sixth Edition, Lea & Febiger, p. 567. |
| McGehee, W. H. O. | A Text Book of Operative Dentistry; 1930, Blakiston's Son & Co., p. 804 and pp. 851-9. |
| Grieves, J. C. | The Dental Cosmos; pp. 1113-1125. |
| Gethro, W. | The Treatment and Filling of Root-Canals; Journal A.D.A., 1919, p. 812. |

Dental Amalgams

THOMAS COWLING, M.A., D.D.S., B.Paed.

Professor of Dental Technology and Metallurgy
University of Toronto

PREPARED FOR
THE BOARD OF THE ROYAL COLLEGE
OF DENTAL SURGEONS OF ONTARIO

PRINTED AND DISTRIBUTED BY
THE CANADIAN DENTAL RESEARCH
FOUNDATION - - - - APRIL, 1935

Bulletin Number Nineteen

THE UNIVERSITY OF TORONTO PRESS

Dental Amalgams

THOMAS COWLING, M.A., D.D.S., B.Paed.

Professor of Dental Technology and Metallurgy
University of Toronto

PREPARED FOR
THE BOARD OF THE ROYAL COLLEGE
OF DENTAL SURGEONS OF ONTARIO

PRINTED AND DISTRIBUTED BY
THE CANADIAN DENTAL RESEARCH
FOUNDATION - - - - APRIL, 1935

Bulletin Number Nineteen

THE UNIVERSITY OF TORONTO PRESS

CONTENTS

PAGE

History of Dental Amalgams	7
Metals Used in Dental-Amalgam Alloys	9
Selection of the Metals	9
Properties Imparted by the Constituent Metals	10
Preparation of the Alloy	12
Weighing and Melting the Metals	12
Mixing, Pouring and Cooling the Alloy	13
Pickling	13
Comminution (Cutting the Alloy)	14
Washing and Screening	15
Annealing (Ageing)	15
Testing the Physical Properties of the Amalgam	17
The Clinical Significance of Physical Properties Tests	18
Flow	18
Crushing Strength	19
Hardness	20
Brittleness and Weakness	20
Staining and Corrosion	20
Expansion and Contraction	21
Manipulation of Dental Amalgams	23
Mercury-Alloy Ratio	24
Trituration	25
Packing and Condensing the Amalgam	28
Pluggers	29
Influence of Packing Pressure	30
Vibrating the Amalgam into Moulds	33
Dimensional Changes Observed in Dental Amalgams	34
Discoloration of Dental Amalgams and Tooth Tissue	35
Serviceability of Dental Amalgams	35
Selecting a Dental-Amalgam Alloy	36
Summary	37

FOREWORD

In this account of dental amalgams no attempt is made to present the complete findings of researches in the subject; rather, it has been prepared solely for the purpose of directing attention to the salient facts regarding the preparation and manipulation of these materials so as to enable dentists to use them to the best advantage. It is very true, unfortunately, that much of the painstaking work involved in the preparation of dental amalgams is to a great extent discounted through the faulty manipulation of this material by dentists. Frequently there is evidence of lack of appreciation of the important place held by amalgams in the field of restorative dentistry. If in any degree this report helps to create a better understanding of the inherent properties of dental amalgams, then its purpose will have been served.

TERMS DEFINED

From time to time criticism is heard respecting the use of the term "dental-amalgam alloy". Many writers prefer the terms "dental amalgam", "silver amalgam", or "dental alloy". As a result, considerable confusion is evident in the literature relating to this subject.

The term "alloy" is used to indicate a substance formed by the bringing together of two or more metals, usually in a state of fusion. As contrasted with this, an "amalgam" may be defined as an alloy of two or more metals, one of which is mercury. In effect then, amalgams are just like any other alloy except that one of the constituent metals must be mercury. Obviously there is need for some term that is truly descriptive of the material used by dentists when restoring teeth to a condition of usefulness. In the early editions of "Practical Dental Metallurgy", by Hodgen and Millberry, the following definition is given:

"The term dental-amalgam alloys comprehends those alloys composed principally of silver and tin, with the addition of small percentages of one or more other metals which, when comminuted and mixed with mercury, form a coherent mass".

Apparently the use of the term "dental-amalgam alloy" is for the purpose of singling it out as distinct from such materials as copper amalgam, or any of the numerous alloys of the precious metals used in dentistry but never brought into contact with mercury. There is the added possibility of confusion of terms when referring to some dental "fusible alloys" in which a small amount of mercury is included, not with the intention of forming an amalgam, but to lower the melting point of the mixture. Within the strict meaning of the term such alloys might quite properly be called amalgams, but ordinary usage precludes such an interpretation. Most frequently the term "dental amalgam" is used and may be interpreted as meaning a comminuted metal or dental-amalgam alloy mixed with sufficient mercury to form a coherent mass. In the account which follows, for the purpose of simplifying the terminology and to avoid redundancy, the term "dental amalgam" will be used as signifying that type of amalgam referred to more correctly as "dental-amalgam alloy".

HISTORY OF DENTAL AMALGAMS

There is no material which is so universally and successfully employed in restoring careous teeth to a state of usefulness as is dental amalgam. This is due, in part, at least, to the extremely high cost of the precious metals, but mostly because of the inherent qualities possessed by this filling material. Even the severest critic will admit that clinical experience has demonstrated the value of amalgam as a tooth-saving material, even when it has been used in a somewhat careless and indifferent manner.

Though dental amalgams have been used for upwards of 75 years, they were not always considered as suitable filling materials. Their introduction to the profession was under unfortunate auspices. The chief merit of these early amalgams consisted in the fact that little skill was required when inserting them in tooth cavities; certainly not the degree of skill called for when manipulating gold foil,—the filling material most in favor with dentists at that time. The first amalgams were poorly prepared and manipulated in a very crude way; as a consequence there was an unusually large number of failures, and ethical dentists everywhere staunchly refused to sanction its use.

It was in Europe that the earliest attempts were made to fill tooth cavities with metals other than gold. As early as 1805, "fusible metals" or low melting alloys of bismuth-lead-tin and of bismuth-lead-tin-cadmium were recommended for filling careous teeth. In 1818 M. Regnart suggested the addition of mercury to still further lower the fusing point of such alloys and so render the task of filling cavities in teeth much easier of accomplishment. Examination of such alloys led to further experimentation with mercury as a solvent of various comminuted alloys and as a result, the first true amalgam used in dentistry had its birth. These amalgams soon replaced the "fusible metals" as filling materials and the property of crystallization of the amalgam mass was carefully studied. It opened up an entirely new line of investigation and in 1826 "Silver Pastes" put in an appearance.

These pastes were sponsored by M. Taveau and contained pure silver and mercury. Soon however, for purpose of economy no doubt, coin silver was substituted for the pure silver and in this way a third metal, copper, found a place, accidentally, in the formula.

America's first introduction to amalgam was in 1833 when the Crawcours used a form of silver paste for the filling of tooth cavities. It was exploited under the name of the "Royal Mineral Succedaneum" and enjoyed an ever increasing popularity with the public, but not with the dentists. So great was the damage done through the

use of these silver pastes by a large group of charlatans, that opposition to their methods soon made itself felt and finally crystallized in the so-called "Amalgam War" which was waged by dentists from public platforms and through the dental journals from 1845 until 1876, and even, intermittingly, for many years after. That the dentists of this period looked upon amalgams as very undesirable filling materials is evidenced by the following resolution passed in 1845 by the American Society of Dental Surgeons, probably the first organized dental society in the world:

"Resolved: That any member of this Society who shall hereafter refuse to sign a certificate pledging himself not to use any amalgam, and moreover, protesting against its use, under any circumstances, in dental practice, shall be expelled from this Society."

Practically all ethical dentists pledged themselves to such action although many of them, later on, admitted that they had never used the amalgams that they had so whole-heartedly condemned and knew of their properties only by report. A few of these certificates are still to be seen among the treasured antiques of the profession and, strange to relate, traces of the old prejudice concerning amalgams are still in evidence in some quarters.

In later years when it became abundantly manifest that a great deal of the opposition to the use of amalgams was not warranted by the facts, the resolution of 1845 was rescinded. From that time on, attention was focussed on the investigation of the properties of amalgam with the result that many new formulas were introduced to the profession. Among the principal investigators of new formulas both in England and the United States were John Tomes, Charles Tomes, T. B. Hitchcock, E. A. Bogue, Thomas Fletcher, and A. Kirby. They were pioneers and much of the later progress in scientific research work on amalgams was due to their efforts.

In the late seventies, J. F. Flagg, S. B. Palmer, and H. S. Chase,—men who held a high standing in the dental profession,—took a very courageous stand; they openly espoused the merits of dental amalgam. They made many contributions to dental literature and on numerous occasions debated the subject on the public platform. This state of affairs continued with the dental profession divided in its opinion regarding the merits of amalgam and very hesitant in adopting this new material, until in 1895 Dr. G. V. Black published his memorable report on the physical characteristics of amalgams. His investigations, though carried on with a rather inadequate physical apparatus, placed alloy making and manipulation, for the first time, on a truly scientific basis and put within reach of every member of the dental profession a modern amalgam which ranked

close to gold in durability and in the protection afforded a tooth from the recurrence of decay.

Since the time of Dr. G. V. Black new and improved designs in testing apparatus have been introduced; the testing technique has been greatly amplified until to-day there is a standardized procedure carried out under governmental approval, which assures the dentist that the best possible filling material is available for his use. Due also to the insistence of a large body of manufacturers of dental supplies throughout the United States and Canada, governmental research and testing departments have been established and by reason of a close collaboration with the manufacturers of dental supplies, these departments are kept in close touch with dental problems as they arise. Much of the expense of these research departments is taken care of by the manufacturers. Their continued support of this work is a guarantee that the products best suited for dental operations will always be available. This is of inestimable value alike to the patient and dentist.

METALS USED IN DENTAL-AMALGAM ALLOYS

In the course of about 75 years since amalgams were introduced in dentistry, many new formulas containing a rather large assortment of metals have been recommended; indeed, practically all of the more commonly known metals have in turn been used. Most of them have been discarded because it was found that instead of contributing desirable properties to the amalgam, they were actually harmful. To-day the typical dental-amalgam alloy contains silver, tin, copper, and zinc. Some have no zinc in the alloy while a few add a little gold. The Requirement of Federal (U.S.A.) Specification No. 356, calls for silver, 64 to 70 per cent.; tin, 26 to 29 per cent.; copper, 3 to 6 per cent.; zinc, 0 to 2 per cent.

SELECTION OF THE METALS TO BE USED IN THE ALLOY

Great care must be exercised when selecting the metals to be alloyed so as to prevent the inclusion of impurities which would very materially upset the balance of the alloy and, in addition, prove a positive danger to the health of the tooth. Corrosion by-products in the mouth might easily be traced to impurities in the metals used in dental restorations. Obviously, metals of a standard of commercial purity are not suitable for dental amalgams. They must be carefully purified to remove any injurious constituent. The following is a list of the more common impurities found in metals of commercial purity only:—

Silver may contain copper, arsenic, antimony, or iron.

Tin may contain arsenic, sulphur, lead, bismuth, antimony, iron, or copper.

Copper may contain arsenic, silver, lead, bismuth, antimony, zinc, or sulphur.

Zinc may contain lead, iron, cadmium, antimony, arsenic, or sulphur.

Mercury may contain lead, tin, zinc, or bismuth.

In addition to insistence upon a high standard of purity in the metals used, it is also necessary to examine the metals for uniformity of crystalline structure. It is found that the crystal structure is almost as important as chemical purity.

PROPERTIES IMPARTED BY THE CONSTITUENT METALS

Silver: Though as already pointed out, it would seem easily possible to secure identical results in alloys when silver of a similar degree of chemical purity is used, irrespective of the method of purification followed, such is not found to be the case. The crystalline structure of the silver has much to do with the properties of the completed alloy, hence manufacturers of dental-amalgam alloys are careful to secure not only a pure metal, but one that has been purified by a process that produces a metal of suitable crystallinity.

In some of the approved text-books on Dental Metallurgy, it is stated that not more than 68 per cent. silver may safely be used in dental-amalgam alloys otherwise the amalgam "will expand beyond control and may prove positively harmful in a tooth cavity". Until recently no person challenged this statement, but now it is found possible and actually beneficial to increase the proportion of silver in the alloy to 70 or even 72 per cent. This increase makes for beauty of luster, better color, greater crushing strength and toughness. It also lessens the tendency to flow and brings about an earlier condition of stability in the completed filling.

Silver and mercury, if used alone as a simple amalgam, would expand on setting to such an extent as to be injurious to tooth structure, (even causing fracture of the tooth) so some metal must be added which will contract sufficiently to take care of the expansion of the silver amalgam. Tin is the metal best suited for this purpose.

Tin: Tin is added to the alloy to the extent of about 26 per cent. partly because of the shrinkage that occurs when tin amalgams crystallize. This shrinkage may be used to counteract the expansion which occurs in silver amalgams. In addition, tin adds to the whiteness of the amalgam and tends to slow up its setting time, thus providing an ample opportunity for inserting and carving the filling. Although a relatively soft metal, tin, when alloyed with silver, in-

creases the hardness and toughness of that metal. Tin also, because of its great affinity for mercury, greatly facilitates the amalgamation of the alloy. In this connection it might be observed that a dental-amalgam alloy which amalgamates very easily, say, by mixing in the palm of the hand, is likely to contain too large an amount of tin. A high grade alloy requires considerable trituration with mercury in order to produce an amalgam. From tests made it appears that an excessive amount of tin in a dental-amalgam alloy is responsible for undue flow in an amalgam filling. This is to be expected because tin and mercury form solid solutions which themselves are somewhat malleable.

Reference has already been made to the importance of the crystalline structure of silver used in an amalgam alloy; the formation and ranging of the crystals differ even in metals of the same chemical purity, and this difference has a marked effect on the physical properties of the amalgams. This applies with an equal importance to tin as it does to silver, because there are marked differences in the various brands of tin. Altogether there are approximately a score or more brands of tin on the market. Even in chemically pure tin, the crystals vary all the way from coarse, uneven forms to those best described as fine, uniform, and thread-like crystals. It is obvious therefore, that great care must be exercised in the selection of the tin which is to be used in the dental amalgam.

Copper: About 5 per cent. of copper is added to a dental-amalgam alloy. If used alone with mercury, it forms the well known copper-amalgam,—a satisfactory and durable filling material. In the dental-amalgam alloy copper acts as a stabilizer; it neither expands nor contracts on setting. It tends to shorten the setting time of the amalgam and imparts great edge-strength to the filling. Copper has less affinity for mercury than have silver or tin and takes up about three times its own weight of mercury. Flow is lessened by the use of copper in the alloy and considerable hardness is imparted to the filling. If used in the correct proportion, copper has little effect upon the color of the amalgam; an excess of this metal would, however, tend to produce a dark filling when in contact with the saliva.

Zinc: Some formulas entirely disregard zinc; others include a small amount, say 2 per cent. This metal is said to increase the toughness of the amalgam, improve the color and impart a smoothness to its working properties. One investigator advances the claim that a small amount of zinc added to the alloy “confers a degree of stickiness to the amalgam that, while not appreciable to the ordinary touch, helps the filling to adhere to the cavity walls”. If this is true, then this type of alloy should produce moisture-tight fillings that would be very effective in tooth preservation.

Gold: A few dental-amalgam alloys contain a small percentage

of gold because this metal is said to improve the cohesive quality of the amalgam. It increases toughness and helps to maintain a white color of the amalgam. Like zinc, gold is said to "assist the amalgam to hug the cavity at the margins". This should also be of assistance in securing leak-proof fillings.

Mercury: The essential purpose of the mercury is to act as the uniting solvent of the various alloy constituents and so produce an amalgam. Mercury materially improves the whiteness of the filling, yet through its affinity for sulphur, may cause a subsequent darkening, particularly if the mercury contains any impurities. For use in dental amalgams, mercury of the highest degree of purity is required. Modern methods of purification have resulted in the production of an extremely pure product which assists materially in keeping the amalgam filling a good color.

Indium: Hitherto a rare metal, indium has recently been used as a constituent of dental white golds. Tests indicate that this metal may also play a useful part in dental-amalgam alloys because it tends to produce surface stability in the alloys in which it is used. In addition to this property it is possible that this metal will reduce the tendency to discoloration so evident in silver alloys, and at the same time increase surface hardness.

PREPARATION OF THE ALLOY

Weighing and Melting the Metals

Having selected the chemically pure metals possessing suitable crystalline structure, the next step is to weigh out the constituents of the chosen formula and then proceed to alloy them.

The fusing together of the constituent metals of a dental-amalgam alloy is, unquestionably, the most important part in the preparation of the alloy. Because of the widely different fusing points of the metals used, the problem of alloying them, without loss by volatilization or oxidation, is not an easy one to solve. To prevent overheating of the molten metals and at the same time to produce a homogeneous mass, free from oxidation products, requires great skill and fine discrimination. Then, again, there is the problem of the absorbed gases. For instance: Silver when molten may absorb (or occlude) as much as twenty-two volumes of oxygen which attempts to escape with great vigor when the metal solidifies. So some means must be resorted to in order to prevent the ill-effects caused by oxidation and the occlusion of gases. Many tricks or devices are made use of in order to produce alloys uncontaminated by oxidation; reducing agents containing carbon are used, or plumbago crucibles hold the metals as they are being alloyed. In this way the carbon is made to combine with the oxygen of the air and so prevent the oxi-

dation of the metals. Unfortunately for this method, some of the carbon finds its way into the molten mass of metal and must be removed. Sometimes pure silica crucibles take the place of the graphite crucibles, and the metals are stirred with rods of pure silica. Again, the metals in a molten state may be poured through fire in order to prevent contact of the molten mass with air. Burning blocks of wood are sometimes placed on top of the molten metals in the crucible for a similar reason. These are but a few of the common devices utilized to prevent oxidation. More effective methods, perhaps, are seen in the types of furnaces used in alloy making. Among these may be noted the ordinary injector furnace, the induction furnace, or the hydrogen gas furnace,—all calculated to produce alloys that are homogeneous in character and free from oxidation products.

Mixing, Pouring and Cooling the Alloy

The molten mass must be well mixed, poured quickly at just the right temperature, and immediately cooled, otherwise there is the possibility of the constituent metals separating out, when poured, due to their differences in specific gravity and lack of affinity one for the other. At times even an experienced operator finds it necessary to remelt the alloy because of difficulty in obtaining a homogeneous mixture of the constituent metals, but such remelting is avoided as much as possible. Remelting almost always results in the burning up of some of the metals, thus seriously altering the composition of the alloy.

Mixing may be done by means of a green stick or by specially prepared stirring rods, such as those made of pure silica, graphite, etc. In some instances the metals are mixed by passing gases under pressure through the molten mass. It is claimed for the induction type furnace that a homogeneous mix is easily obtained without any interference from stirring rods or pressure gases. The green stick method is a simple yet practical one. The sap in the wood prevents the too rapid carbonization of the wood and at the same time produces gases which find their way up through the molten metals, thus aiding in the prevention of oxidation.

The molten mass is usually poured into an oiled mould which produces an ingot suitably shaped for placing on a lathe. The poured metal is chilled as quickly as possible in order to fix the constituents and so prevent their separation.

Pickling the Alloy

The chilled ingot is placed for a few minutes in an acid bath. This removes the oxide film which occurs on the surface of the metal. The acid is then carefully neutralized and all trace of the solutions washed off under running water.

Cutting the Alloy (Comminution)

The cut of the alloy, whether fine, medium, or coarse, has a direct bearing on the working properties, dimensional changes, and the strength of the amalgam. In general terms, the alloy should not be too fine or too coarse; a fine cut means that more mercury is required in the amalgamation process, and though this facilitates the working and packing of the amalgam, it makes for weakness in the filling and produces considerable flow. A coarse cut produces effects that are somewhat opposite to those produced by fine cut alloys.

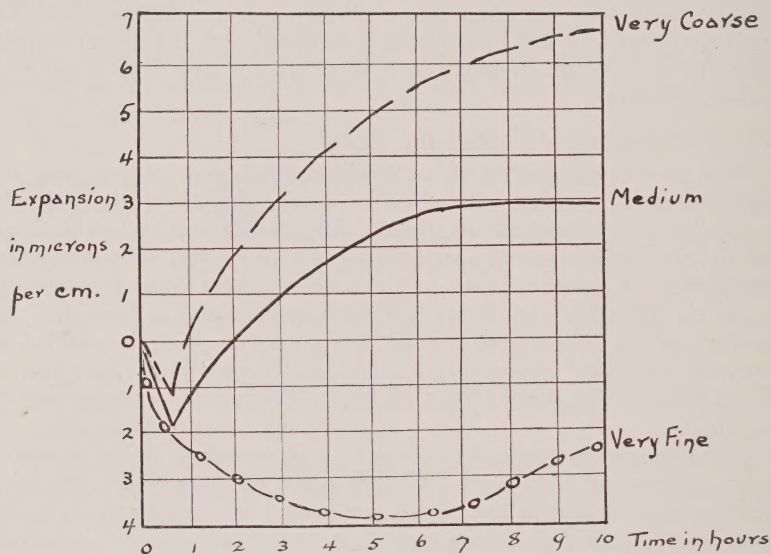


FIGURE 1.—This graph, which is based chiefly upon the reports of Gray, Souders and Peters, as well as tests made in the Faculty of Dentistry, University of Toronto, shows the effect on the dimensional changes of a setting amalgam, due to the variation in the size of the alloy particles. It should be noted also that the change produced by varying the size of the alloy particles is similar to that resulting from the variation in trituration time. (See Fig. 4).

There are three methods used most frequently for cutting dental-amalgam alloys. These are: Filing by hand or machine; cutting with a milling-machine; and cutting with a lathe.

The filed particles viewed under a magnifier, appear more or less rounded in form. When packing an amalgam made from these rounded particles, it is advisable to use a packing instrument with a large face, otherwise the amalgam is inclined to roll under the instrument; condensation becomes difficult.

The product of the milling-machine is in the form of sheet-like flakes or fine shavings cut from the bar of brittle alloy. Some operators contend that such flakes condense better than do filings.

The lathe method produces splinter-like particles or shavings, depending upon the kind of cutting tool used in the lathe. The particles are similar to those produced by a file, but lack the roundness of form. They are frequently referred to as "filings" although not produced by a file. All varieties of sizes are to be found in these "filings" depending upon the kind of cutting edge used in producing them. Obviously this method of comminution lends itself very readily to standardization and for this reason it is the one most frequently used.

The lathe method may also be used to produce "shavings" of the alloy, a form much in favor with some dentists because, being thinner than the filings, the shavings permit the passing of the mercury through the metal with great facility. Amalgamation is completed speedily because of this quick interpenetration.

A recent innovation is that of polishing the alloy at frequent intervals during the cutting operation. This method is said to produce particles of a better color which, when amalgamated, produce a whiter mass than is the case when the older methods of filing (without polishing) are used. This method of cutting and polishing has not been adapted by the principal manufacturers of dental alloys and no published description of the method is as yet available.

Washing and Screening the Alloy

Before they are supplied to the profession, all alloys are washed to remove any trace of grease or oil. It is a mistake for the dentist to supplement this by any further treatment; indeed, positive harm may be done through the use of some of the washes proffered the profession by various dealers.

Screening is for the purpose of producing alloy particles of a uniform size. This is important because the same alloy, amalgamated under identical conditions, may show expansion or contraction according to the size of the alloy particles. (See Fig. 1.) So, it is customary to pass the comminuted alloy through a series of fine screens in order to remove all foreign materials such as pieces of flux, or carbon, and also to separate out the grains of uniform size. Then a magnet is passed through the alloy. This removes any particles of iron which may be there as broken down portions of the file, blades, or other cutting devices used when comminuting the alloy.

Annealing the Alloy

A freshly-cut alloy, rich in silver, is unsuitable for use as an amalgam filling material because it requires a relatively large amount of mercury to complete the amalgamation, sets so rapidly that it is almost impossible to condense it even in a small cavity, and generally

exhibits a very coarse structure. There is a tendency for the amalgam to "ball-up" or spheroid when being packed in cavities and it is difficult to burnish or adapt closely to cavity walls. As the amalgam is worked there is a noticeable sound of crepitation,—a sort of crackling noise—due to the passing of the coarse crystals over each other. This crystallinity is made very evident when the amalgam is worked between the fingers; a definite harshness is felt. The dimensional changes in such an amalgam are also extreme so that it is never advisable to use an alloy in a freshly comminuted condition.

When a molten metal is cast and then suddenly cooled, there occurs a condition of molecular strain in the metal because the molecules are not arranged normally. This strained condition is further aggravated by cutting the metal, hence some form of annealing or "ageing" must be resorted to in order to correct this condition.

Annealing is a form of molecular readjustment or "ageing" and is brought about either in steel or in a dental-amalgam alloy, usually by subjecting them to some form of heat treatment. Actually annealing or "ageing" is a form of recrystallization. In the case of a dental-amalgam alloy, the particles are subjected to a temperature of about 120° F. for from 2 to 7 days, or a temperature of 212° F. for about 30 minutes. The degree of heat used, and the duration of the heat treatment are determined by the formula. As with all metals, annealing of the amalgam alloy is a function of both time and temperature,—the lower the temperature used, the longer the period of annealing. The same effect may be obtained by simply allowing the alloy to stand or "age" for a period, say, of one year. This does not harmonize with modern production methods so the process is hastened by artificial means.

Some of the early investigators of dental amalgams thought that the annealing process was actually an oxidation process, but this view has been entirely abandoned. It is extremely difficult to produce an amalgam with metals whose surfaces have become oxidized. Annealing causes a rearrangement of the crystals with the result that the original characteristics of the alloy are restored and the alloy becomes softer and easier to amalgamate. This beneficial effect is noticeable for about one year, after which time more mercury is required to effect amalgamation and the amalgam becomes slow setting. There is also a slight diminution in edge-strength. Some manufacturers, knowing that alloys change their properties with age, date the packages and offer the suggestion that alloys more than a year old should be exchanged for fresh material.

That there should be some form of correlation between annealing methods used with dental-amalgam alloys and the dimensional changes observable in the setting amalgam, is to be expected. So, it is found that an expanding alloy will expand less, and a contracting

alloy will contract less when properly annealed. In general terms it may be stated that annealing increases strength in high silver-content alloys, slows up setting time, reduces the amount of mercury required for amalgamation, minimizes dimensional changes, and improves the working properties of the amalgam. There is some evidence in support of the opinion that many alloys supplied to dentists are not thoroughly annealed; many are subjected only to a superficial treatment with the result that their working properties, after the alloy has been stored for some time, change considerably. Some alloys that at first expanded an amount sufficient to meet the American Dental Association's specifications, later on were found to have become contracting alloys. The annealing had not been done properly and as a result, all fillings made from such alloys subsequently gave evidence of shrinkage away from cavity margins.

TESTING DENTAL AMALGAMS

Until quite recently, purchases of dental supplies were made by the profession on the basis of eloquent advertising or persuasive sales talks. Little or no attempt was made to establish the merits of any material by scientific tests carried out by reliable and unbiased investigators. Some dentists found a satisfactory material for their needs by a sort of trial-and-error method. This was costly and unreliable.

To-day, due to the active co-operation of the manufacturers of dental supplies and various dental associations, together with the assistance of Research Bureaus of the Canadian and United States Governments, it is possible to obtain detailed and reliable information respecting the suitability of any material for use in dentistry. In the United States a truly great work is being carried on by the Research Commission of the American Dental Association. The Survey of Amalgam Alloys, a report to the Research Commission by the Bureau of Standards, had the effect of not only selecting the alloys best suited for dental requirements, but also traced the cause of many of the failures of amalgam restorations in the mouth. It was found that many of these failures were due to the faulty manufacturing methods used in the preparation of the alloys as well as imperfect manipulative technique followed by the dentist. As a result, specifications were set up for the guidance of the manufacturer so that to-day it is possible for dentists to buy with confidence, knowing well that the purchased product has met the requirements set up by authoritative bodies.

Testing the physical properties of dental materials results in a standardization of product and this assures the production of high quality materials. With such materials available, dentists have only to follow a correct procedure of manipulation in order to secure

satisfactory results. Patients also benefit in that they are assured of the best possible service for the fee paid. Unless the manufacturers and dentists co-operate, the one in producing a satisfactory material, and the other in manipulating it to best advantage, then much of the skill and expense involved in the preparation of dental supplies is entirely lost. Both the patient and the dentist are losers.

The United States Government Master Specifications for dental-amalgam alloys, Federal Board Specification No. 336 is as follows:

Amalgams shall possess the following features, known as satisfactory working qualities:

1. Thorough amalgamation in 3 minutes.
2. Absence of granular or sandy consistency when amalgamated.
3. Susceptibility to carving for at least 15 minutes after amalgamation.
4. Susceptibility to receiving and retaining a polish 24 hours after amalgamation.

Chemical Composition.—The chemical composition shall be within the following limits:—

Silver	65 to 70 per cent.
Tin	26 to 29 per cent.
Copper	3 to 6 per cent.
Zinc	0 to 2 per cent.

Ultimate Compression Strength.—The average ultimate compressive strength values of three or more tests shall not fall below 2,500 kilograms per square centimetre (approximately 35,500 pounds per square inch.)

Flow.—Specimens subjected to a constant pressure of 250 kilograms per square centimetre (approximately 3,550 pounds per square inch) shall not show more than 5 per cent. flow (i.e. more than 5 per cent. shortening in length of the specimen) in a period of 24 hours.

Setting Changes.—Twenty-four hours after amalgamation the length shall have increased between 1 and 10 microns per centimetre. If at any time during the test a contraction of more than 4 microns per centimetre is detected, the alloy shall be rejected.

Details as to methods of conducting the tests are given, and the temperature at which the tests are to be made is set at 20° C to 25° C.

The Clinical Significance of Physical Properties Tests

Flow: Amalgams tend to flow or to change their shape without any break in continuity, when a constant pressure is exerted upon them. This is the property which permits of burnishing the margins of a metallic filling. The amount of such flow must not be too great, for obviously the filling might creep over cavity margins and even find its way into interproximal spaces, or over occlusal surfaces thus setting up severe discomfort which might result, ultimately, in the loss of the tooth. Again, any metal which possesses this property of flow in too great a degree, is not adapted for contouring, especially where pronounced contact points are to be restored.

Tin possesses the property of continued flow under pressure and imparts this property to many of its alloys. On the other hand,

silver and copper will flow continuously only if the pressure is constantly increased. A good dental amalgam will break before flowing beyond a limited amount. Excessive flow in the amalgam usually signifies the presence of too much tin. If the property of flow is not at all in evidence, then such amalgams are likely to be brittle and deficient in crushing strength; they will not afford the tooth structure that element of support intended. Briefly stated: The chief factors governing flow in an amalgam filling are the constituents of the alloy, the percentage of mercury in the amalgam, the manner of trituration, the size and kind of alloy particles, and the pressure used in packing the filling.

The method of determining the amount of flow in any amalgam, is to place a small short cylinder of the material, about 5 mm. diameter, under a 70 pound weight, allowing this constant pressure to continue for 24 hours. This load, which is equivalent to approximately 3550 pounds per square inch, is placed on the test specimen 3 hours after amalgamation. Automatic micrometers are used to measure the shortening or flow of the specimen. As already pointed out, the American Dental Association's specifications call for less than 5 per cent. flow in a dental amalgam in 24 hours under a pressure of 3550 pounds per square inch, such test to begin 3 hours after packing the test specimen.

This test for flow in amalgams is an essential one because it is the dentists' only guarantee of the quality of the alloy. It gives assurance that restorations made from the tested alloy will prove satisfactory in dental restorations. An interesting observation when making these tests, is that any amalgam which meets the flow requirements satisfactorily, will assuredly have good crushing strength also.

Crushing Strength

This is one of the most important properties of dental amalgams and is measured by any of a great variety of dynamometer machines. Tests are usually conducted with small specimens having a diameter of about 5 mm. The American Dental Association's specifications require that the crushing strength of amalgams shall exceed 35,500 pounds per square inch, 5 days after packing the test specimen. Amalgams which meet this requirement will offer sufficient resistance to occlusal stress and to the continuous impact stresses present in the process of mastication. The bevelled edges of amalgam fillings possessing this crushing strength will also withstand masticatory stresses. While it may be successfully argued that few persons are able, when masticating food, to bring into play any force approximating 35,500 pounds to the square inch, it is equally true that many patients do possess great strength in the masticatory muscles and these cases have to be provided for. In view of the difficulty of estimating the force available in each individual, it is

but the application of common sense to protect all by providing a filling material strong enough to meet the requirements of even the strongest masticatory equipment.

The crushing strength of an amalgam filling may decrease as much as 20 per cent. when the saliva comes in contact with the amalgam during the packing process. There is no evidence however of the saliva having any effect on the setting changes commonly observed in amalgams.

Hardness

An amalgam filling must be sufficiently hard to withstand the ordinary stresses to which it is subjected. Hardness may be defined as the ability to withstand penetration. The Brinell ball penetration test is an example of this. Here a ball of a known diameter is forced into the material to be tested for hardness; the depth of the penetration is taken as a measure of hardness and is signified by a number. The accredited specifications for dental amalgams makes no mention of hardness tests, but most of the approved amalgams have a Brinell hardness of between 40 and 65. Some register as high as 70. This range is equivalent to that of soft inlay gold.

It has been emphasized by those who are investigating the changes that take place in the tissues surrounding the teeth, that a filling material that is too hard will cause a condition of traumatism, which, if not corrected, may result in the loss of the tooth. For this reason many hard cast metals have had to be discarded. But no criticism of this kind has ever been made with respect to amalgams. An amalgam filling will wear away at just about the same speed as does natural tooth substance, hence the danger of traumatic injury to the surrounding tooth tissues is reduced to the minimum.

Brittleness and Weakness

Good edge-strength is one of the essentials of a satisfactory dental amalgam, for, lacking this property, the marginal edges of the filling soon break down and a space results into which food packs. Caries soon follows. It is found that amalgams that are hard and possess good compressive strength, with the proper amount of flow, also have good edge strength; that is, they are devoid of brittleness and weakness. These amalgams afford ample protection for cavity margins.

Staining and Corrosion

There are no well-defined tests for the discoloration of amalgams. Few references are made to such a test in the recent literature on amalgams. One such reference occurs in a report, "A Third Survey of Dental Amalgams 1932-1933" by G. C. Paffenbarger and T. Sweeney.

"Some of the amalgams tested appeared to be very dirty in that they blackened the hand and the mortar excessively. They would also leave a dark smudge when the plastic amalgam was drawn across a piece of white paper".

Practically all dental amalgams become stained in the presence of sulphur compounds. This is due to the affinity of silver, copper, and mercury for sulphur. Tin, zinc, and gold decrease this staining tendency. Amalgams in direct contact with gold or platinum corrode readily, due to the generation of a galvanic current. A test for staining properties of amalgam, that is sometimes used, consists in mulling the amalgam in the palm of the hand two minutes after it has first been amalgamated for one minute in a mortar. The hand should, of course, be first washed with soap and water, then rinsed several times in clear, running water, and finally washed in alcohol. It is a question whether this test is a fair one, because if an amalgam does darken the skin it does not necessarily follow that it will stain tooth substance.

A dirty mortar and pestle may cause considerable discoloration of amalgam. A quick and efficient method of cleansing is to put a solution of hydrochloric acid in the mortar and work it around by means of the pestle, then thoroughly wash under running water.

Expansion and Contraction

Amalgam has long been recognized as an important filling material possessing valuable tooth-restoring properties. It has been equally well known that a contracting amalgam may shrink sufficiently to cause the loss of a tooth through bacteria and fluids finding their way into the space between the filling and the cavity walls. On the other hand, cases are on record where teeth have actually been split by the expanding action of the amalgam. Many amalgam restorations present the picture of the filling expanding beyond and over the margins of the cavity, thus affording an ideal lodgement for food particles. These are instances of "reaction expansion". This term is used to distinguish such reactions from those due to thermal conditions. Too great a reaction expansion must be avoided if amalgam restorations are to prove satisfactory. The ideal amalgam is one which expands just sufficiently to keep it in close contact with the cavity walls, thus providing a truly leak-proof filling.

It is not easy to measure the dimensional changes that take place in an amalgam as it is setting, because of the extreme accuracy required and the necessity for using small samples. Dr. G. V. Black, using instruments that were inadequate for this purpose, reported that the properties of expansion and contraction in dental amalgams were inherent properties imparted by the formula and the method of manufacture, and that these properties could not be altered by

varying the manipulative technique. Modern instruments show that this statement is not correct; that the methods of triturating and packing an amalgam have a great deal to do with the subsequent dimensional changes observed in the filling. The best instruments for measuring these small dimensional changes are the Interferometers or Dilatometers.

The Interferometer makes use of the interference of light waves and consists, essentially, of two plane glass plates, which are held apart by a suitable separator. The Interference Viewing Instrument is a device for viewing the interference fringes formed by reflections from the two plane surfaces. Measurements that are too small to be ascertained by mechanical means may be accurately determined by the Interferometer. A change in the size of an amalgam specimen even as little as 0.005 micron* or 0.0000002 inch is demonstrable by means of this apparatus. When dental amalgams are being tested, measurements of expansion and contraction are usually made to 1—100,000 of an inch.

Assuming that one micron is equal to 0.00004 inch, it will readily be understood why an amalgam filling that contracts, say, 10 microns when setting, will provide ample space between the cavity wall and the filling, sufficiently large to accommodate a veritable army of bacteria. It is undoubtedly the contracting amalgam that has brought this filling material into disrepute.

There are many types of Dilatometers in use in various scientific departments, the type chosen depends largely upon the use to which it is to be put. A. W. Gray developed a Thermostated Amalgam Dilatometer by means of which it is possible to follow, from minute to minute, dimensional changes as small as 0.05 micron, or 1—500,000 inch. Even greater degrees of sensitivity can be registered, if necessary.

Using this instrument to investigate the dimensional changes in dental amalgams, Gray reports his findings in an article "Metallographic Phenomena Observed in Amalgams", published in the Journal of the National Dental Association, 1919, Vol. VI, as follows:

"The typical reaction expansion of a dental amalgam is characterized by four consecutive stages: (1) rapid contraction to a minimum; (2) somewhat slower expansion to a maximum; (3) considerably slower contraction to a second minimum; (4) very much slower expansion to a second maximum".

Ordinarily only two of these reactions,—the initial contraction and expansion are observable.

To guard against excessive contraction or expansion in dental amalgams, the American Dental Association's specifications call for a contraction of not more than four microns per centimeter

*A micron is equivalent to a thousandth of a millimeter.

(4—10,000 inch per inch), and an expansion at the end of 24 hours of not more than 10 microns per centimeter.

Out of a very large number of tests made it is possible, in only a relatively few instances, to register the first contraction; this apparently takes place, in many of the tests, while the amalgam is still in the mortar, or before the sample can be transferred to the testing apparatus.

Many of the new alloys which contain an increased amount of silver, say 70-72 per cent., do not give evidence of the initial contraction which was a characteristic property of the older 65-68 per cent. alloys.

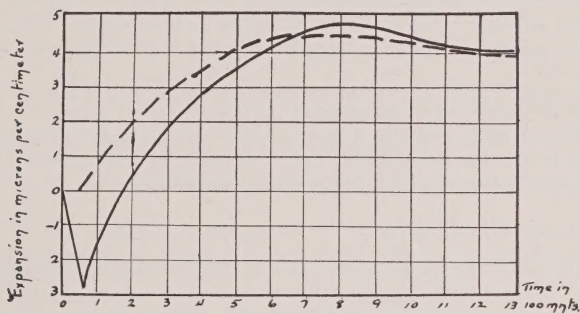


FIGURE 2.—A typical reaction-expansion curve of a setting dental amalgam. The unbroken line is taken from Gray's report on amalgams and shows an initial contraction followed by an expansion for alloys containing approximately 65 per cent. silver. The broken line is based upon tests made in the Faculty of Dentistry, University of Toronto, and shows no initial contraction for alloys containing approximately 70 per cent. silver. (It is extremely difficult to measure or even detect the initial contraction because this frequently takes place before the test piece can be placed in the testing apparatus).

MANIPULATION OF AMALGAMS

A survey of the literature dealing with the subject of dental amalgams shows a commendable interest in the methods of preparation and in the results of numerous tests conducted with a view to determining their physical properties, but there is a noticeable shortage of information regarding manipulative procedures. There are, possibly, two reasons for this neglect. First, the investigations, in many instances, have been conducted by men who have never practiced dentistry; naturally, they are interested in the problem of amalgams as they appear, say, to the physicist or engineer. Second, the pronouncement made by Dr. G. V. Black many years ago, to the effect that the formula and method of manufacture of the alloy alone

govern the behaviour of the amalgam when used as dental filling material, which statement carried with it the implication that the operator was completely at the mercy of the manufacturer and it made little or no difference how the material was manipulated.

More recent researches have proven beyond any doubt that even when a cavity has been prepared with great care and skill and is then filled with an amalgam made from the best alloy obtainable,—even then, the filling may prove faulty because of incorrect amalgamation and condensation methods. Dr. Black recognized the fact that the working of amalgam was not an easy thing, for in his Text Book of Operative Dentistry he says: "It is difficult to learn its manipulation and more difficult to secure perfect results regularly, filling after filling". Even as recently as September, 1934, Dr. W. E. Harper is quoted in the Dental Journal of Australia as saying:

"Many experienced operators provide the necessary packing compression but sadly fail to apply it with sufficient uniformity at all points in cavity angles and along cavity walls and also fail to provide the necessary plasticity. Among many in my profession the necessity for uniformity of application of the forcible compression seems to be either unknown or neglected".

The Mercury-Alloy Ratio

The proportion of mercury used when amalgamating an alloy influences to a great extent the properties of a dental amalgam, especially the reaction expansion time. When there is a deficiency of mercury it is difficult to obtain a smooth plastic amalgam; the mass is apt to be coarse and difficult to condense in small spaces. After it sets, cracks may occur throughout the filling and the dimensional change is characterized by marked contraction. At no time is there any evidence of expansion, consequently from the time the filling is placed in the tooth it will have leaking margins.

Some manufacturers of dental-amalgam alloys supply an automatic measuring device for use with their alloys so as to ensure a sufficient amount of mercury being used for the amalgamation. As already pointed out, there is a serious danger in using too little mercury, but no harm can result from using too much mercury. A safe rule to follow is to have a slight excess of mercury in the amalgam. The proportion of mercury retained in a filling does not necessarily depend upon how much excess mercury is used when amalgamating; it is governed by the pressure employed in condensing the amalgam in the tooth cavity. The greater the pressure used, the less the percentage of mercury retained, and the stronger will be the filling.

When too little mercury is used in the amalgam it is found: (1) that it is difficult to bring about the amalgamation, (2) the amalgam is very difficult to condense in a tooth cavity, (3) there is poor adaptation to cavity walls and into undercuts, (4) the structure of the amalgam is very coarse, (5) cracks appear throughout the amal-

gam, (6) the mercury is very slow in diffusing through the mass, (7) volume changes are exaggerated and prolonged, (8) the amalgam filling is weak and breaks down readily under the stresses of mastication, (9) the amalgam is slow setting.

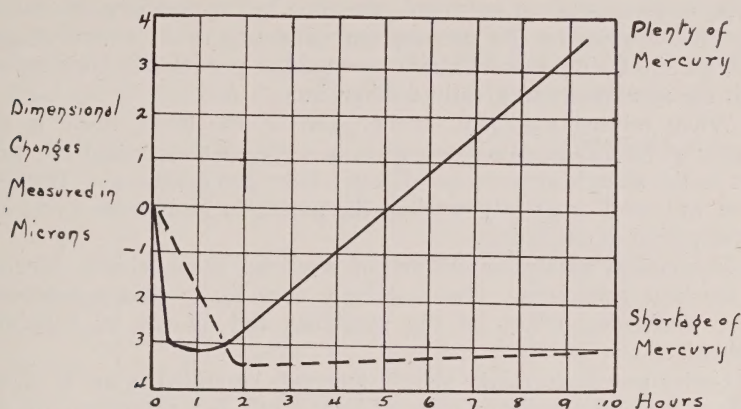


FIGURE 3.—Showing the effect of reducing the mercury-alloy ratio (number of grams of mercury used with each gram of alloy) upon the dimensional changes in a setting amalgam.

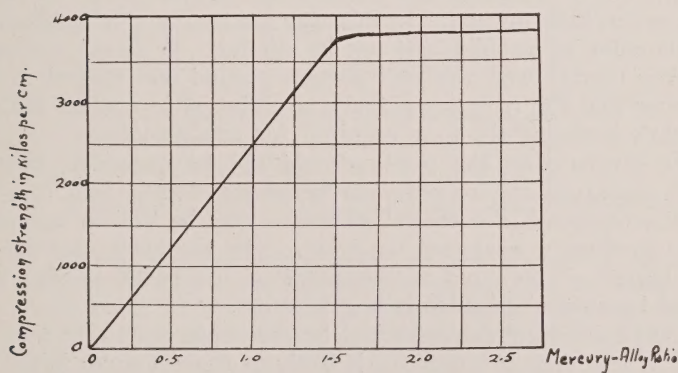


FIGURE 4.—Showing the effect upon the crushing strength of amalgams when the mercury-alloy ratio is changed. This graph, taken from Gray's publication, "Metallographic Phenomena in Amalgams", shows that the full strength of an amalgam is not developed until the mass of mercury is at least 1.5 times the mass of the alloy.

Trituration or Mixing the Alloy and Mercury.

Many methods are in use for bringing about the union of alloy and mercury; some are very objectionable and should never be countenanced. For instance, the rubbing together of the amalgam con-

stituents in the palm of the hand, in full view by the patient, is, to say the least, very unsightly. Actually this method does not produce good results because it is not possible to use sufficient pressure to cause the mercury to penetrate the alloy particles. There is, in effect, just a superficial wetting of the alloy by the mercury. A similar objection applies to the preparation of amalgam in rubber finger stalls or similar devices in which case rubber particles become mixed with the amalgam and greatly weaken it.

When mixing amalgam in the palm of the hand, there is the danger of having the amalgam take up some of the natural oils present in the skin, also portions of scurf from the epidermis. Both of these will tend to greatly weaken the amalgam and cause excessive discoloration of the filling.

Mechanical amalgamators are of doubtful value, chiefly because of the heat generated. Heat,—even a very little,—has a relatively great weakening effect on the amalgam and should be carefully avoided.

Under no circumstance should mercury be added to an amalgam after it has been mixed; such additions call for a renewal of the trituration process and this very substantially weakens the amalgam.

The most satisfactory method for preparing a dental amalgam is by the use of a mortar and pestle made of glass with the contact surfaces carefully ground. In this way the mercury is incorporated with the alloy by rubbing and not by stirring. A recent innovation is a glass mortar with the well portion ground and shaped in such a manner that the mercury globules are always in contact with the alloy thus lessening the time required for amalgamation.

The pressure on the pestle should not be excessive, but just enough to cause the mercury to penetrate deeply into the alloy particles, otherwise the crystal structure may be broken up unduly and so produce a weakened amalgam. The amalgam may also become heated. Too rapid a movement of the pestle is also to be avoided because of possible heat generation.

It has been fully demonstrated by numerous tests that a mixing period of less than two minutes is likely to show a small initial contraction followed by a definite and, in some instances, excessive expansion. Prolonged trituration, that is, upwards of five minutes, results in great shrinkage and a weak amalgam. In both these cases the amalgam is likely to exhibit poor compressive strength together with poor adaptability. The best results are obtained when the alloy and mercury are mixed together for a period of from three to four minutes. A few manufacturers recommend a trituration time of from two to three minutes for their alloys.

In order to illustrate the importance of correct trituration time, the Bureau of Standards, Washington, conducted experiments using

the same alloy and the same percentage of mercury, but varied the mixing period, with this result: The alloy which was triturated for about 3 minutes gave an expansion in 24 hours of 5 microns; the same alloy triturated for 30 minutes gave a contraction of 15 microns. These are extreme cases, no doubt, but they serve to emphasize the importance of timing the mixing period. Few operators do this. Frequently a dentist carries on a conversation while busy with the mortar and pestle and, depending upon the interest taken in the sub-

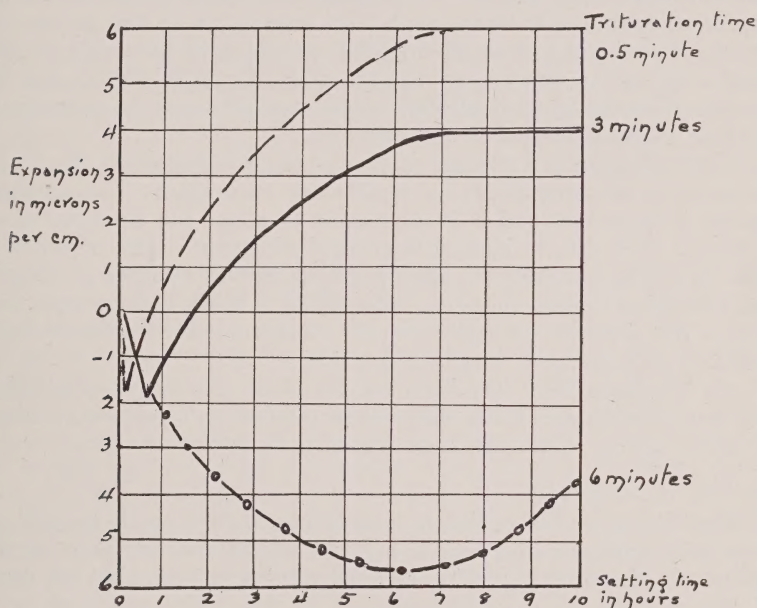


FIGURE 5.—This graph, based on the reports of Gray, Souders, and Peters, also the results of tests made in the Faculty of Dentistry University of Toronto, shows the effects of trituration time upon the dimensional changes of amalgams. (Compare Fig. 1 and Fig. 4). In addition to results shown above, it may easily be demonstrated that prolonged trituration periods greatly reduce the crushing strength of amalgams.

ject under discussion, the amalgamation process may be of a short, medium, or prolonged duration. The effect of this may later be discernible in the filling where contraction rather than expansion is in evidence. Too little trituration, as with too little mercury in the amalgam, produces voids through the shrinkage of the amalgam.

Prolonged trituration not only produces a leaking filling, due to the contraction of the amalgam, but it also weakens the filling because the crystals of amalgam begin to form while it is yet in the

mortar and continued trituration breaks these crystals down. A very weak amalgam is produced because of the constant setting up and breaking down of the crystals.

Many operators like to remove the amalgam from the mortar and knead it in the palm of the hand so as to obtain a desirable texture. If such a method be deemed necessary, then the amalgam should be first placed upon a napkin and then kneaded out of contact with the skin. Roll the amalgam into the form of a thin cigarette and cut into small pieces. The excess mercury should never be expressed from the entire mass before inserting into the cavity. If the operator insists upon placing the amalgam in the palm of the hand without an intervening napkin, then the skin should first be washed thoroughly with alcohol to remove all trace of natural oil or loose adherent matter on the skin.

The following is a picture of an amalgam filling when the amalgamation is brought about by insufficient trituration: The amalgamation is imperfect and it is impossible to adapt the amalgam close to cavity walls due to its coarse-grained structure. The mercury is slow to diffuse through the alloy particles and this causes prolonged and extensive volume changes. The filling is likely to be a weak one due to the presence of spaces in the amalgam,—the result of poor mercury diffusion and insufficient condensation.

An amalgam that has been subjected to prolonged trituration will show cracks and folds and will be difficult to condense or adapt to cavity walls. The shrinkage will also be excessive.

Packing the Amalgam

The filling of the cavity is best begun with a small portion of very soft amalgam, working it into all angles and surfaces of the cavity. With the next portion of amalgam begin squeezing out some of the excess mercury; then place it in the cavity and pack with sufficient pressure to bring the excess mercury to the surface. Remove this mercury with a spoon-shaped instrument*. Repeat this process, squeezing out the excess mercury from each portion of amalgam before placing in the cavity, and pack with pressure, removing the pressed out mercury after each addition of amalgam. Continue until the cavity is overfilled, using comparatively dry amalgam to finish off the filling. This is a convenient means of using up the excess mercury remaining in the amalgam that is already in the cavity. Amalgam cloths are now available at the dental supply houses and these may be used to squeeze out the mercury, with the aid of pliers if necessary. A pressure of 9 or 10 pounds should be exerted when packing the cavity. As soon as it is practicable, start to carve the filling. Leave the final polishing until the next sitting.

*Gold cylinders at one time were used to remove the mercury, because of the great affinity of this metal for mercury.

Packing Time: If the cavity to be filled is a large one requiring a considerable mass of amalgam, it becomes rather difficult to keep the mass in a workable condition until the cavity is completely filled; the amalgam crystallizes before the filling is completed. Allowing all the mercury to remain in the mass of amalgam, slows up the setting time and the excess mercury can then be removed from each portion just before it is placed in the cavity. The working time is thus prolonged. It must not be assumed, however, that such a period can be protracted indefinitely. Actually, the waiting period acts on the amalgam in much the same way as does excessive trituration; it tends to produce contraction. The amalgam mass begins to set before it is placed in the cavity, and packing disturbs the crystallization; a weakened filling results. A filling once started should be completed as quickly as possible and saliva should be excluded from the cavity during the packing process. Saliva weakens and discolours the filling.

Pluggers

Some very interesting and unusual experiments have recently been conducted by the Dental Investigation Committee, Department of Scientific Industrial Research, England, in which pluggers made of silver, copper, and tin were used when packing the amalgam test-specimens in the hope that the excess mercury might be removed by the process of amalgamation with the plugger. These experiments show that "both tin and copper pluggers had the effect of wiping out the initial contraction which occurs on setting, while the silver plugger had little, if any, effect. The amalgam packed with the copper plugger shows an initial expansion followed by a marked further expansion after 10 days. This expansion remains constant until the 60th day, approximately, after which a contraction sets in".

Recently the Faculty of Dentistry, University of Toronto, in collaboration with The Ontario Research Bureau, conducted a series of tests of selected dental-amalgam alloys. Professor Ellis supervised the tests and reported that in no instance was he able to secure any indication of initial contraction in the amalgams tested. The reason for this apparently lies in the fact that all of the samples were condensed in moulds by the use of a heavy gauge pure copper wire used as a tamping rod. These results confirm the report of the finding of the English research committee referred to above, in that the copper plugger appears to "wipe out the initial contraction which occurs on setting".

There is little need for a great variety of packing or condensing instruments in amalgam work. Pluggers of excessive area are to be avoided. It requires an instrument with small serrated points to adopt the amalgam to approximal margins, but when filling in the center and bulky portions of the filling, or for finishing off, larger

and smooth-end instruments may be used. They condense the amalgam well without any tendency to "draw". The smaller the instrument the greater the pressure exerted on the amalgam, and the better the condensation of the filling. However, the instrument must not be so small as to cut up or chop the amalgam by reason of too deep a penetration of the mass. The smooth faced instruments may be used to burnish the plastic mass against the cavity walls.

Influence of Packing Pressure.

The ambition of all dentists is to be able to place in a tooth-cavity a non-leaking filling, because it is quite apparent that any filling which leaks at the margins, is a poor filling and sooner or later must be replaced if the tooth is to be saved. In securing such a leak-proof filling when using amalgams, packing pressure is of supreme importance.

Individuals vary remarkably in their ability to exert pressure on packing instruments; some, without any conscious effort are able to bring into play a pressure that is much greater than that obtained by others who purposely put forth every effort to produce a maximum pressure. The difference is due, of course, to the muscular strength possessed by individuals in the forearms and fingers. A simple demonstration of this variation in pressure may be made by pressing down on the pan of an ordinary kitchen scale with a pencil or dental instrument held in the fingers. Repeating this test at frequent intervals will result in the strengthening of the muscles involved and make possible more efficient condensation of amalgam in tooth cavities.

One method of determining the amount of pressure used on a hand instrument is as follows: Assume that a circular plugger one eighth inch in diameter is used for plugging the amalgam, and that the operator uses a pressure of 10 pounds; then the pressure of 10 pounds is concentrated on an area of a circle the diameter of which is one-eighth inch, or the equivalent of approximately 815 pounds per square inch.* If a smaller instrument is used for packing the amalgam, say, one with a diameter of one-twenty fourth of an inch, then the pressure trebles and becomes 2,445 pounds per square inch. It is advisable therefore, when packing amalgam into a cavity, to use an instrument with a small surface area, but not, as has already been stated, small enough to cut up the amalgam. The heavy pressure forces the mercury into every particle of the alloy and finally brings all surplus mercury to the surface where it can easily be detected and removed. This makes for a stronger and faster setting amalgam. The greater the packing pressure used, the more intimate becomes the union between the mercury and the alloy. This is de-

*Area of a circle = diameter squared multiplied by .7854.

sirable, because as long as there is liquid mercury present an amalgam will not completely set. Under good pressure the liquid mercury disappears by combining with the other metals to form a solid inter-metallic compound. It is also found that as the packing pressure increases there is a progressive shortening of the time required by the amalgam to reach a state of stability, that is, when all dimensional changes are complete. This is very desirable because it makes possible the dismissal of a patient within a reasonable time after the filling has been inserted without fear of its breaking down under ordinary pressure.

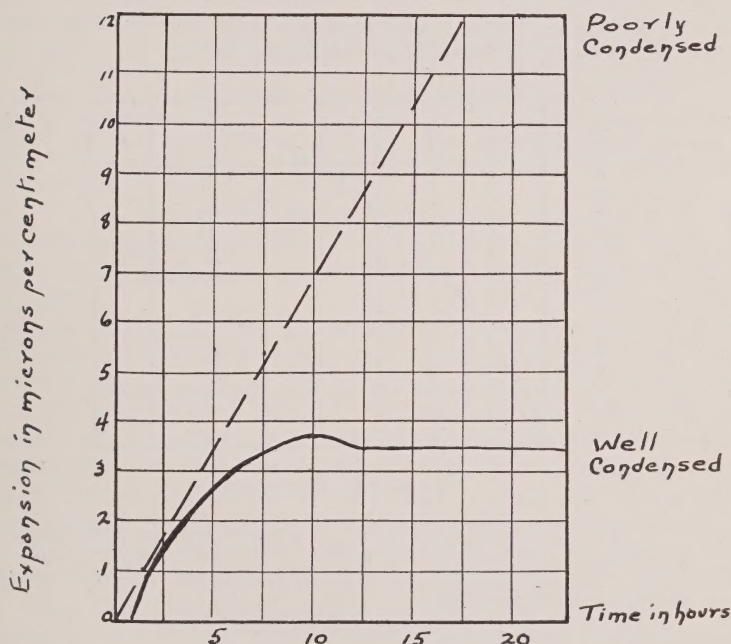


FIGURE 6.—This graph, published by Dr. A. J. Rothen in his report: "A Contribution to the Study of Amalgams", shows the effect of packing pressure on the expansion of dental amalgams.

As early as 1918, in a paper read before the American Institute of Mining Engineers, Arthur W. Gray, Ph.D., pointed out that the packing pressure exerted a marked influence on the crushing strength of amalgams when packed in tooth cavities. He showed that "other things being equal, the crushing strength (S) increases directly as the logarithm of the packing pressure (P); so that, within the limits of experimental error, it can be expressed by a formula, $S=A+B \log P$,

where A represents the strength that would correspond to packing a filling without condensing, and B expresses the rate at which the strength increases with increase in the logarithm of the pressure used". It becomes quite apparent from this that an increase in packing pressure produces an increase in the crushing strength of the amalgam.

From the point of view of clinical dentistry, the lesson taught by these tests is that the tighter the packing, the better the filling, because heavy packing not only adds to the strength of the amalgam, but it also shortens, very considerably, the time required for the filling to complete its dimensional changes and become stable. Moreover, it results in much better adaptation of the amalgam to the cavity walls and so reduces the possibility of leakage.

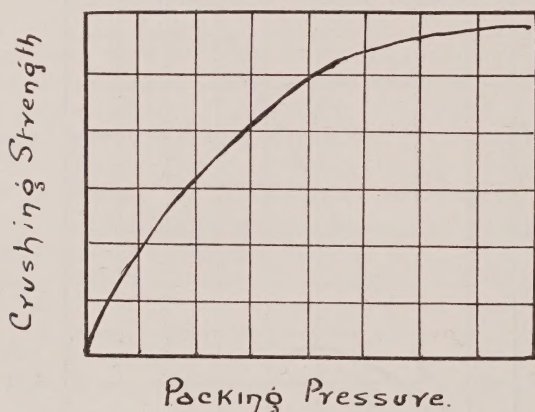


FIGURE 7.—Showing the effect of pressure used in condensing an amalgam in a tooth cavity, upon the ultimate strength of the filling. As the packing pressure increases the resistance to crushing stresses increases.

The problem of how to secure a leak-proof amalgam filling is discussed by L. Cooper in the January, 1933, issue of *The Dental Journal of Australia*. He says:

"To get sufficient pressure on the walls of a cavity with amalgam to make a perfect non-leaking filling, the packing must be done with a pressure on the cavity walls of 2,000 pounds to the square inch. A high-grade alloy, if packed with this pressure, will show a permanent pressure of not less than 160 pounds to the square inch. This will make a perfect non-leaking amalgam filling".

No explanation is given as to the method of calculating the pressure on cavity walls, but the statement is interesting because it emphasizes the necessity of using considerable pressure when packing

amalgam. Some operators may be apprehensive lest damage be done the tooth through the use of heavy pressure packing. There is little danger involved, however, for as determined by Mr. W. Souders, Physicist, Bureau of Standards, Washington,* the compressional strength of human dentine is approximately 30,000 pounds per square inch, and in some instances may be 35,000 pounds.

In his "Operative Procedures", Dr. G. V. Black says: "The whole secret of perfect amalgam work is contained in the one word, "compression". A modified form of this opinion is shared by Dr. W. E. Harper, Chicago, in a paper entitled "Our Most Frequent Amalgam Failures". He says:

"My test records indicate that unless the amalgam is packed in a very plastic state against the surrounding cavity walls and into its angles, enough to cause the amalgam to exert a pressure of over 130 pounds to the square inch at all points, the perfection of the adaptation will prove very doubtful. . . . We moderate our packing force sometimes to such extent that we fail to express the dangerous excess of mercury. The retention of this excess of mercury will ruin any amalgam filling that is daily exposed to the fluctuating temperatures of the mouth".

Dr. Harper has introduced a new burnishing technique to be used when condensing amalgam into tooth cavities, by means of which the excess mercury is removed and so produces a strong, stable and leak-proof filling.

Recent finding of Souders and Peters go to show that all amalgam fillings in the mouth shrink and expand 12 to 13 microns when exposed to mouth temperatures of a rather wide range such as that due to ice cold and hot drinks. The tooth structure expands and contracts to a less extent. In view of the fact that the temperature change is greater than the setting change, its importance becomes at once apparent. Obviously we cannot avoid the dimensional changes due to temperature; we must therefore do something by way of compensation. The amalgam filling must be packed with sufficient force to cause a permanent pressure against cavity walls, then when the thermal contraction of the filling takes place, it is modified by that pressure and no actual separation of the filling from the cavity walls occurs.

Vibrating Amalgam into Moulds

Recently ceramic workers have introduced a method of securing an amalgam model of the cavity in which a fused porcelain inlay is to be placed, preparing such a model from an amalgam that expands an amount just sufficient to compensate for the contraction of the porcelain as it fuses. The difficulty is to obtain such an amalgam. The matter having been referred to the Bureau of Standards, Washington, the following information was given:

*Measurement and application of Certain Physical Properties of Dental Amalgams.

"There are no amalgams marketed which expand as much as .2 per cent. upon usual manipulation. There is a technic however, whereby greatly increased expansion may be secured when high-silver alloys are used. This requires that the amalgam be vibrated into place in a manner similar to that used when vibrating models of artificial stone."

Attention is directed to this because it may be used to advantage when preparing cast gold inlays by the indirect method.

Dimensional Changes in Dental Amalgams

The typical reaction expansion curve of a high-grade alloy mixed with an adequate amount of mercury, and packed with proper pressure, exhibits, according to Gray, "a slight contraction followed by a slow expansion, which in turn is followed by a still slower contraction". (See Fig. 5) It is to be noted, says Gray, "that the dimensional changes of an amalgam prepared from the same alloy, can be profoundly altered by altering the manipulation". This opinion is diametrically opposite to that expressed by Dr. G. V. Black, who held the view that "Shrinkage and expansion of the amalgam used is not under the control of manipulation by the operator. This can be controlled only in the selection of the alloy to be used. . . . The question of shrinkage and expansion resolves itself exclusively into that of the correct balancing of the metals in the alloy".

Since the time of Black's investigations many new and efficient instruments for fine measuring have been introduced so that research workers to-day are much better equipped for their tasks.

It is true that the manufacturer of dental-amalgam alloys has under his control the selection of the metals to be used, also the annealing and comminution of the alloy,—all being important in producing a good filling; but the dentist, too, must accept his share of the responsibility. The method of trituration, the amount of mercury, the packing pressure,—all these influence, in a marked degree, the changes through which the amalgam passes before reaching a state of stability.

In the Physical Review, Vol. XIX, No. 4, April 1922, Arthur W. Gray, Ph.D., offers an explanation for the peculiar alternation of contraction and expansion that a dental amalgam undergoes during and after the process of hardening. He finds that the first contraction is due to the solution of the alloy in the mercury and the formation of Ag_3Hg_4 . Crystallization of this compound quickly follows and this is accompanied by an expansion. Long after the amalgam has begun to harden there is a gradual inward diffusion of the free mercury coating the alloy particle, resulting in more solution, more reaction and finally, crystallization. This accounts for the slowing up of the reaction after the first change has been noted.

Once more it becomes apparent that amalgam should be packed into tooth cavities under pressure so that the mercury may more speedily

penetrate through the mass and in this way bring about the completion of all dimensional changes in the shortest possible time. This hastens the condition of stability in the filling and lessens the danger of fracturing the amalgam when it is under the stress of mastication.

Discoloration of Amalgams

The darkening of amalgam fillings may be due to several causes, one of which is the use of mercury that has become contaminated with sulphur. To unclean mortars and pestles can also be traced many other cases of discoloration; an easy way to clean these is to wash with a dilute solution of hydrochloric acid. Other instances of unpleasing colour in amalgams are traceable to the practice of mixing them in the palm of the hand; the natural oils and the scurf of the epidermis are taken up by the amalgam with a subsequent discoloration. Evidence of this is to be seen in the dark stain remaining on the skin after handling the amalgam.

The silver and copper constituents of a dental-amalgam alloy also have a marked affinity for sulphur, but with the use of new formulas and better methods of preparation, the discoloration is not as pronounced as formerly, especially when mercury redistilled by modern methods is used. Keeping the amalgam free from contact with saliva during the packing process is also of assistance in maintaining a good color in the filling.

Amalgam in contact with gold or platinum restorations in the mouth are likely to blacken due to galvanic action.

The fineness of the alloy particles is said by some investigators to have a bearing on the question of discoloration; the finer the alloy, the darker the amalgam becomes. There is little evidence in support of this statement.

An amalgam filling properly polished will keep its color much better than one which is not polished. Polishing brings into play the inherent property of flow possessed by all high-grade amalgams, and as the metallic surface is polished or burnished, it becomes denser and there is less likelihood of food particles adhering to the filling and causing discoloration.

Polishing of amalgam filling should always include the removal of all overhanging gingival margins; these are a prolific source of irritation which frequently results in extensive loss of tissue.

Serviceability of Amalgams

A high-grade alloy, mixed with plenty of mercury, and packed in a tooth cavity with good pressure, will produce a filling that is practically age-proof; that is, there will be no retrogression in compressive strength and no leakage at the margins will ever be in evidence.

In the accompanying graph there is no evidence of decrease in

crushing strength at the end of 10 hours; the same result is shown when the amalgam is tested after a much greater lapse of time, say 10 months or even 10 years.

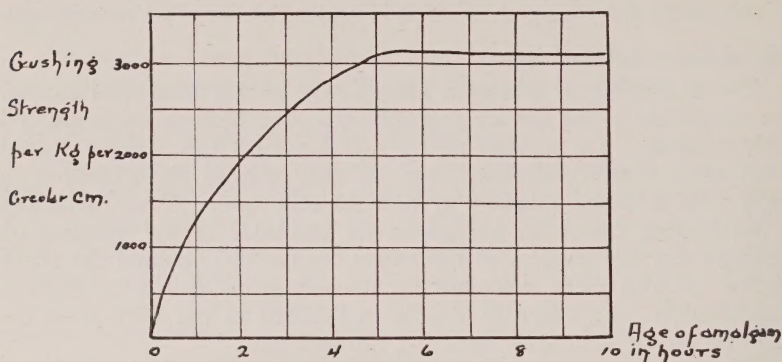


FIGURE 8.—Showing the progressive and rapid increase in strength of an amalgam filling that has been properly triturated and condensed in the tooth cavity with adequate pressure.

Selecting a Dental-Amalgam Alloy

A few years ago it would be easily possible to find many alloys used in dentistry that contained as little as 50 to 55 per cent. silver; to-day it is doubtful if any alloy is sold that contains less than 62 per cent. Silver in recent years has not been a costly metal, so there has been little need for economizing in its use; to-day (August 1934) there are indications of a marked appreciation in the value of silver, so that the need to reduce the amount of silver in amalgam alloys may once more be felt.

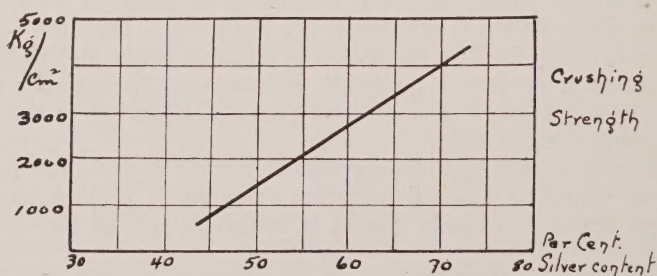


FIGURE 9.—This graph, by Dr. A. J. Rothen ("A Contribution to the Study of Amalgams") and readily substantiated by routine tests, shows the effect of the silver content in the alloy upon the crushing strength of the amalgam.

It was the expressed opinion of authorities, until recently, that no more than 68 per cent. of silver could be safely used in dental amal-

gams; now upwards of 70 to 72 per cent. alloys are in common use. This increase in silver content produces a much superior alloy. A dentist should never use any alloy that cannot be graded as a high-silver alloy, because a high-silver content amalgam in a few hours becomes as strong as a low-silver content amalgam ever becomes. At the end of 24 hours the high-grade amalgam will be approximately 50 per cent. stronger than one with a low-silver content, and ultimately its advantage in compressive strength may exceed 75 per cent. Low grade amalgam alloys are almost sure to produce contracting amalgams due to the excessive use of tin in the formula.

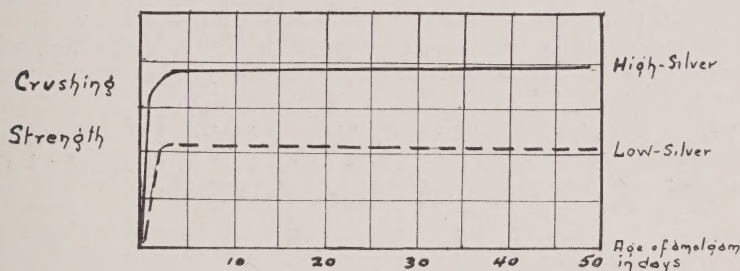


FIGURE 10.—This graph shows that an amalgam low in silver content never attains the crushing strength of one rich in silver, that is, over 65 per cent.

SUMMARY

1. In earlier years, amalgams used as dental filling materials were condemned, chiefly because low-grade alloys were amalgamated, in many instances, with a still lower grade of mercury.

2. To-day, most of the dental-amalgams in common use, meet the requirements of the American Dental Association's specifications. They possess the inherent properties necessary for satisfactory and serviceable fillings.

3. The main objective, when inserting amalgam in a tooth cavity, is to restore the normal functioning of that tooth by means of a leak-proof filling. This is possible only if care is exercised by the dentist in selecting a high-grade alloy, mixing it with a slight excess of pure mercury for about three minutes and then condensing the amalgam under good pressure.

4. Adequate packing pressure together with sufficient burnishing against cavity walls will aid materially in producing a leak-proof filling.

5. Overtrituration of alloy and mercury must be avoided, also the addition of mercury after the amalgam is prepared. Both of these greatly weaken the filling.

6. A good color in the completed filling is most likely to occur only when a high-grade alloy is amalgamated with pure mercury in a clean mortar, and when the amalgam, during the packing process, is kept free from contact with saliva.

7. A lowering of crushing strength together with some indication of brittleness may result from the contact of amalgams with saliva during the packing process.

8. All amalgam restorations should be polished and particular care taken to remove all overhanging margins.

9. No matter how skillfully a dental-amalgam alloy may have been prepared by the manufacturer, it is likely to produce a weak and contracting amalgam when placed in a tooth cavity, if the dentist is indifferent to or completely ignorant of correct manipulative procedures.

10. An amalgam made from a high-grade dental-amalgam alloy properly manipulated will produce a filling that is practically leak-proof and will show little if any deterioration with age.

Red Bone-Marrow in Human Jaws

BY

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S. (ENG.)

*Research Professor of Periodontology,
Faculty of Dentistry, University of Toronto*

BULLETIN NUMBER TWENTY

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

1933

Red Bone-Marrow in Human Jaws

BY

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S. (ENG.)

*Research Professor of Periodontology,
Faculty of Dentistry, University of Toronto*

BULLETIN NUMBER TWENTY

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

1933

PRINTED IN CANADA

RED BONE-MARROW IN HUMAN JAWS*

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S. (ENG.)

*Research Professor of Periodontology, Faculty of Dentistry,
University of Toronto*

IT is hardly necessary to call attention to the fact that scientific information concerning the bone-marrow in human jaws is of fundamental importance to dental pathology and dental diagnosis in their broader aspects. Until further enlightenment is forthcoming it is obvious that in some of its most important phases, diagnosis must remain in a state of comparative empiricism which is in no way worthy of the entailed responsibilities. Our knowledge of the varieties of bone-marrow in the human jaws and its reactions and degenerations is still very incomplete and this inadequacy is certainly a matter of some moment to the dental profession at the present time. The dearth of references in dental text-books and the current literature to the presence, distribution and significance of red bone-marrow in the human maxillae and mandible points at once to the lack of information on this subject alone. This brief contribution is written in the hope that the importance of the problem will be more fully realized by dentistry as a whole, and that it will serve as a stimulus to further work in this field of investigation.

OSTEOLOGY

There are several varieties of bone-marrow. Beattie and Dickson¹ have described them under the following classification of normal and pathological; viz.: (1) Primitive or Embryonic Marrow, (2) Red, "Lymphoid" or Formative Bone-Marrow proper, (3) Yellow or Fatty Marrow, (4) Fibroid or Sclerotic Marrow and (5) Gelatinous Marrow. According to these authorities, "the medullary cavities of the bones are, early in development, filled with a tissue composed of cells mucoid or "myxomatous" in type,

*In this original study of bone marrow Dr. Box has shown that red marrow is found in the human jaw-bones and may have a profound influence upon dental diagnosis and treatment. This study is progressing and Dr. Box will make a further report in the near future, dealing particularly with the relationship of marrow to bone.

WALLACE SECCOMBE, *Dean.*

possessing numerous branching and interlacing processes. These are in histological structure and appearance similar to the cells found in other mucoid tissues in the foetus; and in this situation, they afterwards develop into the adenoid reticulum or connective tissue framework of the marrow, in the interstices of which appear about the fourth month of foetal life or a little earlier, the haemopoietic cells proper." Red marrow is formed by the proliferation and differentiation of these cells.

On macroscopic examination, normal red bone-marrow is red or reddish in colour. Yellow marrow is composed largely of fat cells, resembles subcutaneous adipose tissue, and is yellowish in colour. All the bones contain red bone-marrow at birth and in early childhood, but in certain situations with advancing age there is a gradual substitution of red marrow by the yellow variety. This has been termed a process of physiological 'degradation'. According to Piney's investigations of the naked-eye anatomy of the bone-marrow in 1700 post-mortem cases, as reported in the *Lancet* (Sept. 9th, 1922, p. 572) this observer found that "all the bones except those of the cranium contained the marrow until puberty, when a small mass of fat appeared just below the centre of the shaft in the long bones". In the normal adult, the red marrow, according to most authorities is found in the short, flat and irregular bones, especially the sternum, ribs, vertebrae, and cranial bones, and in the proximal epiphysis of the femur and humerus, and at the periphery of the yellow marrow in the diaphyses of these bones. In these regions, the red marrow undergoes a much less degree of fatty substitution, but as pointed out by Beattie and Dickson, even in these situations there is a progressive increase in its amount. Should there be a need for increased production of blood-cells formed in the marrow as a result of a variety of stimuli, there is present, therefore in the yellow marrow as well as the red, a potentiality for the development of the blood-forming elements. As stated by Piney²: "The myeloid tissue, which does not undergo physiological atrophy, retains an enormous power of hyperplasia which can manifest itself in a very striking manner, even in chronic infections, but is most extensive in cases of myelosis and pernicious anaemia where the formative tissue may again reach such a size as to fill the bones in a manner similar to that normal in infants".

While reference has just been made to the presence of red bone-marrow in flat and irregular bones of the normal adult, specific data

on the marrow-content of adult human jaws have been difficult to obtain in the available literature. According to Cunningham's Anatomy³ when a bone is fresh, the cavities of spongy bone are filled with red marrow. The maxillae and mandible certainly contain spongy bone. What then is the average normal content of this spongy bone in the human adult?

In order to solve this problem, a large amount of material would necessarily have to be examined and preferably with the microscope. It is felt that the findings of the writer shed some light on the subject, and to some degree at least afford an answer to the question. The following observations were made on exactly 100 blocks of tissue removed from human jaws. Yellow bone-marrow was noted in 75 blocks. Definite zones of red bone-marrow were present in 20 blocks. Myxomatous and fibroid marrow were also observed in a number of cases. The predominance of yellow or fatty marrow was characteristic of the group in which the ages were known as well as that in which the ages were unknown. A careful examination of the findings has convinced the writer that even in early adult life, the bone-marrow in the average normal case is of the fatty or yellow variety.

RELATIONSHIP OF HISTOLOGICAL STRUCTURE OF MARROW TO FUNCTION

Bone-marrow consists of cells and fibres. The latter act as a supporting structure and the former are of several different types although it is not improbable that they are all differentiation products of the undifferentiated mesenchymal cell which in all probability normally exists in this tissue. The more differentiated cells are however of several different varieties. In the first group to be discussed are those which originate from the haemocytoblast or myeloblast which in turn originates from the undifferentiated mesenchymal cell and has the potentiality to differentiate into all the cells of the erythrocyte series, the granular leucocyte series, and the megakaryocytes and platelets. The second series of cells of importance in the bone-marrow are the littoral or lining cells of the vascular channels which are a part of the reticulo-endothelial system. The third group of cells of importance are the fat cells.

Thus considering the functions of these various cells in the

marrow, the function of this tissue as a whole could be considered under three separate headings, viz.:

1. The function of bone-marrow in producing certain blood-cells.
2. The function of the bone-marrow as a unit of the reticulo-endothelial system (immunity, blood-destruction, phagocytosis, etc.).
3. The function of the bone-marrow in fat storage.

Thus the appearance of bone-marrow may at any time represent the result of the tasks placed upon it. For instance in pernicious anaemia, where both blood-production and blood-destruction are markedly increased, one would expect to see the evidence of a hyperplasia on the part of the erythrocyte series of cells together with a marked demonstration of phagocytosis of imperfect red blood-cells on the part of the littoral cells of the reticulo-endothelial system. After extensive haemorrhage one would expect to see only a hyperplasia on the part of the erythrogenic cells, and it is quite understandable that a stimulus of this nature would lead to the phenomenon of the haemopoietic tissue encroaching upon the fat.

THE RELATIONSHIP OF MARROW TO BONE

Bone-marrow is surrounded by bone-tissue which consists of a matrix containing bone-cells in lacunae and which is lined on all sides by a layer of osteogenic cells. These form the deep layer of the periosteum, and as endosteum line the marrow cavity together with the Haversian canals. These cells are furthermore often called 'osteoblasts' which term however does not seem to be quite as accurate as the term 'osteogenic cells'.

Thus it is seen that the marrow proper is usually if not always separated from the bone-matrix by a layer of osteogenic cells. These are specialized units possessing the ability to differentiate into osteoblasts, chondroblasts, or osteoclasts (Ham⁴). That the relationship between bone and marrow is something which is very definite may be indicated by the fact that metaplastic bone when it develops in abdominal scars or old calcified tuberculous areas is usually found complete with marrow. It is evident that there are certain factors, particularly of a mechanical nature which influence the structure of bone proper. Furthermore because of its function

as a calcium reservoir of the body, it is known that its structure is markedly altered in certain disturbances of calcium metabolism. On the other hand, it is also known that in diseases which make demands upon the marrow, the relationship of the marrow to bone may be altered. Thus the balance between the marrow proper and bone proper, although appearing to be something inherent in the tissues, may be modified when one or the other is unduly called upon.

THE SIGNIFICANCE OF RED BONE-MARROW IN ADULT HUMAN JAWS

As stated previously, on examination of 100 different blocks of tissue removed from human jaws, 20 blocks exhibited definite zones of red marrow. Taking into consideration only those cases of which the ages are known, the Agnew material in this regard being of special value, it is of interest to note that red bone-marrow was found in all the age groups from 25 to 65 years of age. In the majority of cases, the presence of red-marrow appeared to be focal in nature, and the zones varied greatly in extent. Several examples were found in and above the maxillary tuberosity. Other examples were noted in the bone around upper and lower molars and bicuspids. One example was seen in the bone associated with an upper cuspid but no examples were found about the upper or lower lateral and central incisors. Two examples were noted in extraction-spaces, in each case an upper first molar.

One of our problems is the significance of these widely distributed zones of red bone-marrow. What explanation have we to offer for the presence in adult human jaws of these tracts of blood-forming tissue? Three possibilities at once present themselves.

In the first place, are we dealing with remnants or vestiges of the original red marrow that have not undergone the process of physiological 'degradation' into fatty marrow? Secondly, because of the focal nature of their distribution, is it probable that the establishment of these regions of red marrow is initiated by certain local stimuli, *e.g.*, as in trauma, exemplified in tooth extraction, traumatogenic occlusion, pulp-extirpation, and root-canal filling; or by infection, gingival and periapical?

In the third place, are these zones produced through the proliferation and differentiation of the haemopoietic cells in the

potential areas of the fatty marrow, brought about by the increased demand for blood-cells that characterizes certain general conditions of disease? It is not expedient in this brief article to discuss the reactions of the bone-marrow in disease. However it is recognized that in many diseased conditions, both in the red and yellow marrow, rapid proliferative changes take place. The process is termed an erythroblastic one when the change is featured by the increased production of red blood-cells, and leucoblastic when there is an increased production of white blood-cells. According to Beattie and Dickson, "usually when the tissue is first stimulated to proliferate, there is increased production of all varieties of marrow-formed blood-cells". They have stated further, "Soon, however, in most cases, the tissue is found to produce more particularly the variety of cell for which there is special demand and the reaction becomes either leuco or erythro-blastic in type, though in some cases both changes may occur simultaneously in the same marrow". Leucoblastic marrows are found in association with the majority of acute infective diseases, local, *e.g.*, inflammation, abscess-formations and general, *e.g.*, pneumonia, septicaemias, etc.; and also in myelogenous and lymphatic leukaemia. Erythroblastic marrows are found in the anaemias, secondary and pernicious.

As to the explanation of the significance of the presence of red marrow in adult human jaws the writer feels that in all probability the three classes just described may be represented. The evidence in some of its phases, viz., the focal distribution and the proof of trauma, as in extractions, points to the probable operation of local factors.

Nevertheless, as the distribution of normal red marrow in the ribs may also be focal, as revealed in a recent examination of beef-ribs, together with the fact that in the average normal marrow of human adult jaws, the fatty variety is predominant, and taking into consideration the available case-histories of some of the subjects and a further study of the different microscopic pictures presented, the writer has come to the conclusion that general agencies in many cases also are at work. Experiments on rabbits, in the writer's laboratory in the University of Toronto whereby pronounced secondary anaemias were produced, have helped to confirm this viewpoint. (Figs. 1 to 10.)

RABBIT EXPERIMENTS

The following experiments were carried out in an endeavour to obtain certain data on the bone-marrow of rabbits, particularly of the jaws, in experimental anaemia produced by haemorrhage. Twelve rabbits in all were taken, six experimental animals and six controls. By repeated bleedings from the ears of the experimental rabbits severe secondary anaemias were produced. At each bleeding, haemoglobin tests were made and blood-smears taken and stained by the Giemsa Method. The first experimental rabbit was bled twenty-four times in twenty-five days, with a total loss of 354 c.c. of blood. The haemoglobin dropped from 85 per cent. to 35 per cent. and the blood-smears showed changes characteristic of a pronounced secondary anaemia. On the twenty-sixth day, this rabbit was chloroformed, as was the control, and certain bones including the femora, ribs and jaws were placed in 10% formalin preparatory to decalcification, embedding and sectioning. The femora and mandibles of both rabbits were also radiographed.

Complete histological findings on the bones of these two rabbits are not available at the present time. The data obtained from these experiments as a whole will be presented at a later date. Nevertheless certain striking changes have already been observed.

The femoral bone-marrow of the experimental rabbit shows almost complete transformation into active blood-forming tissue (Fig. 11). This hyperplasia is marked, as is easily noted when a comparison is made with Fig. 12 which shows the average normal proportions of fatty and cellular tissue in the femur of the control rabbit. The marrow of the mandible of the experimental rabbit in certain zones below the molars shows almost complete transformation into blood-forming tissue. This hyperplasia is definitely focal in nature, as adjacent zones of fatty marrow show no apparent proliferation of the haemopoietic cells (Fig. 13). In approximately the same region in the mandible of the control rabbit, where, the hyperplasia occurred in the mandible of the experimental rabbit, a very small number of haemopoietic cells is noted (Fig. 14). The malar process of the superior maxilla shows almost complete transformation into blood-forming tissue (Fig. 15). In approximately the same region of the control rabbit, the marrow is of the yellow or fatty variety (Fig. 16).

RESORPTION OF BONE IN RED MARROW PROLIFERATION

The writer has observed microscopically two examples in human jaws where the bony trabeculae are smaller in size and farther apart in certain zones of red marrow than the other trabeculae in the same specimens (Figs. 17 and 18).

In this relation, the following statements are of great significance. Coats:⁵ "In anaemias, and more particularly in pernicious anaemia, there is a recurrence to the condition of red marrow in the shafts of the long bones, and there is frequently an atrophy of the bony lamellae so as to accommodate the altered marrow". In a discussion of leukaemia this author has further said: "There is also in many cases an increase in the marrow at the expense of the osseous tissue, as in anaemia". Macewen⁶: "In certain forms of anaemia absorption and thinning of the bones occur". Beattie and Dickson⁷ (in describing changes in the bone-marrow in pernicious anaemia): "The fatty tissue disappears and the medullary cavities of the bones become enlarged by the absorption of the spongy and even of much of the compact bone". These authorities have also shown in a coloured plate in their text-book, the gross absorptive changes in the trabeculae of the spongy bone, in leucoblastic transformations occurring in the upper portions of the shaft of the femur associated with acute lobar pneumonia, rheumatic pericarditis and septic peritonitis. In a case of chronic septicaemia, partial erosion of the compact bony walls of the medullary cavity was demonstrated.

The hypothesis is suggested that certain zones of rarefaction as revealed in radiographs of the jaws, diagnosed as chronic osteitis and known as so-called "residual infection" may be found to be adaptive enlargements of the medullary cavities to accommodate the proliferated and expanded marrow.

In sections of the superior maxilla of the first experimental rabbit, certain areas have been observed in which the bone in close contact with the proliferating red marrow shows an eroded edge and is apparently being resorbed under the stimulus of the expanding marrow (Fig. 19). Certain sections of the mandible of the same animal show generally a much greater number of osteoclasts than equivalent sections of the control animal. Sections of the femur of the experimental rabbit show certain changes in the trabeculae where the bone presents a myxomatous appearance and altogether

a poor type of bone structure (Fig. 20). While unquestionably, the early material shows certain bone changes, no attempt will be made to interpret them as a whole until a much greater amount of experimental tissue has been thoroughly studied.

In conclusion it is felt nevertheless, that these findings presage a changing viewpoint in the diagnosis of obscure rarefactions of the bone of the jaws, and a plea for a more conservative attitude is put forth until specific data are obtained on the correlation of well-taken radiographs and microscopic sections of the tissues. There is an imperative need at the present time for greater information on the relation of bone-marrow proper to bone proper, and on the reactions of both in low grade infections.

BIBLIOGRAPHY

¹Beattie and Dickson: Textbook of Pathology, p. 580, G. V. Mosby Company, 1926.

²Piney, A.: Recent Advances in Haematology, p. 40, The Macmillan Company of Canada, 1928.

³Cunningham's Anatomy.

⁴Ham: "Cartilage and Bone"; Special Cytology, Edition 2. Paul B. Hoeber Inc., N.Y., 1932.

⁵Coats: A Manual of Pathology, p. 464, Longmans, Green & Co., 1903.

⁶Macewen: The Growth of Bone, p. 23, 1912.

⁷Beattie and Dickson: Textbook of Pathology, p. 582, G. V. Mosby Company, 1926.

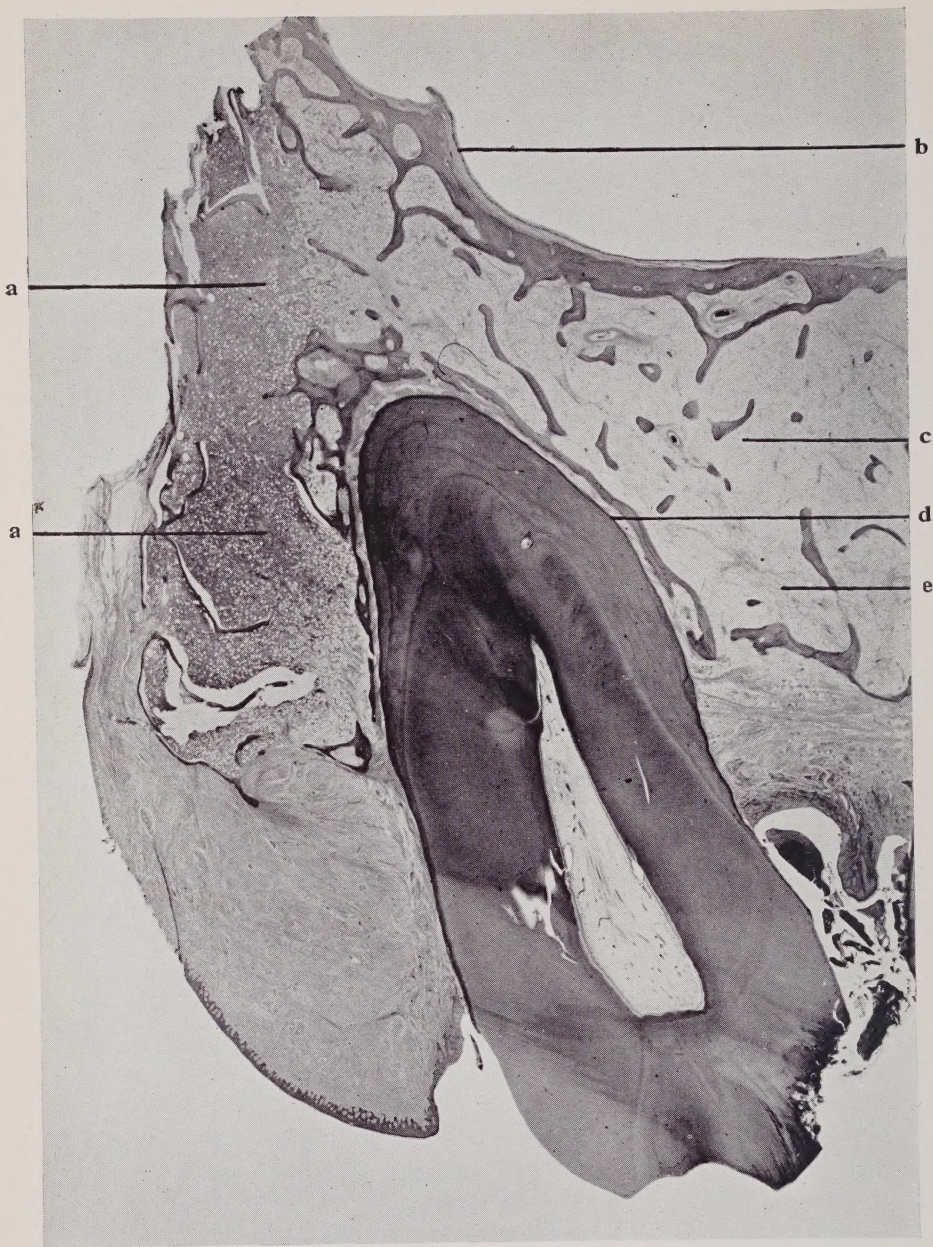


Fig. 1.—Red bone-marrow in human superior maxilla. The tooth shown in this illustration is the third molar. Note distal to the tooth and extending from the crest of the tuberosity almost to the floor of the maxillary sinus, the large zone of red marrow. (Agnew material)

- a, large zone of red bone-marrow; b, floor of maxillary sinus; c, fatty marrow;
d, third molar; e, second molar extraction-space.

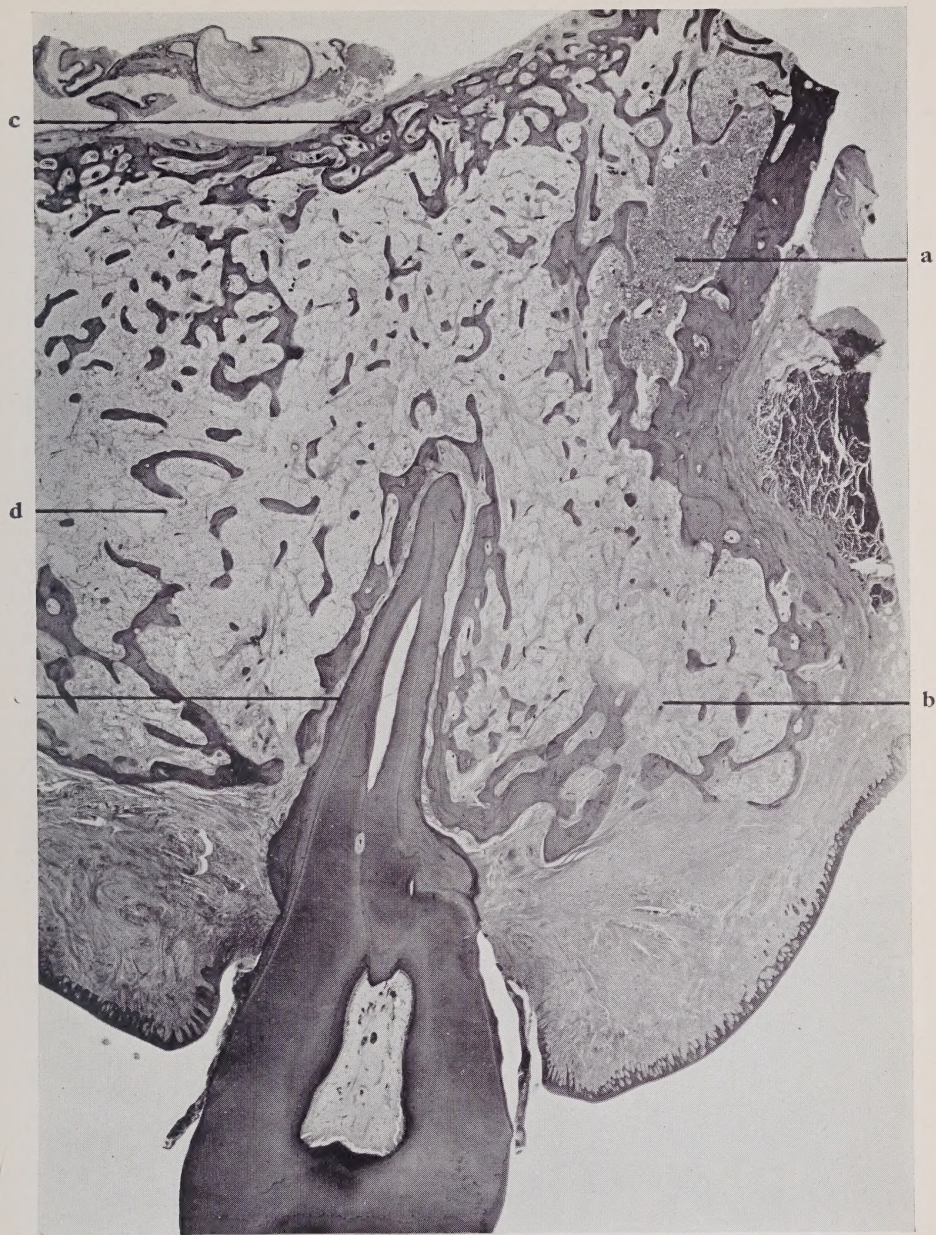


Fig. 2.—Red bone-marrow in human superior maxilla. In this illustration a small zone of red marrow is to be noted above and distal to the root-tip of the tooth shown. The tooth is the third molar, the second molar having been lost. (Agnew material)

a, zone of red marrow; b, fatty marrow in tuberosity; c, floor of maxillary sinus;
d, second molar extraction-space; e, third molar.



Fig. 3.—Red bone-marrow in extraction-space of upper first molar (human). In this illustration there is a general distribution of red marrow throughout the entire section. It extends from the crest of the bone to the floor of the maxillary sinus, and from the alveolar bone of the second bicuspid (right) to the alveolar bone of the second molar (left). (Agnew material)

a, red marrow; b, floor of maxillary sinus; c, second bicuspid; d, second molar.

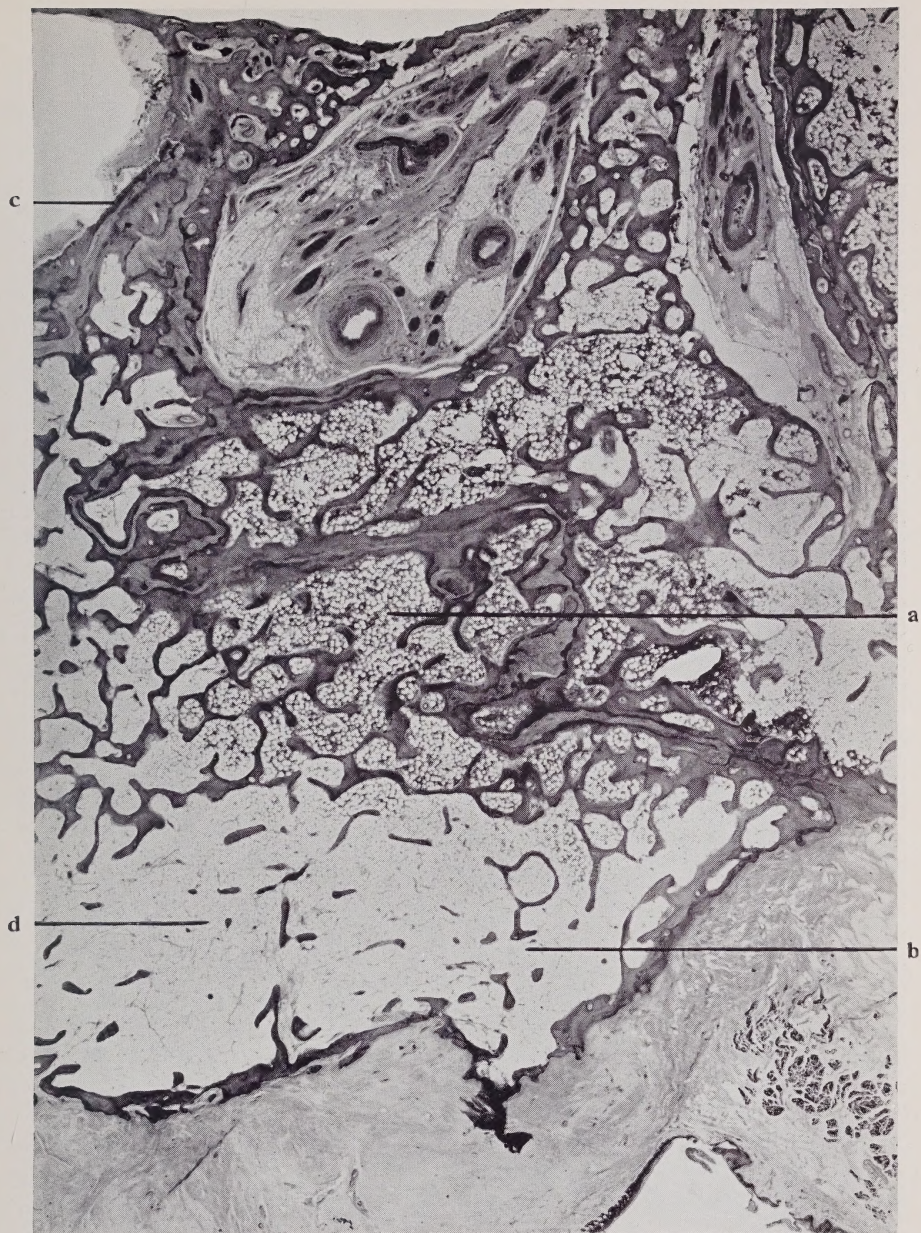


Fig. 4.—Red bone-marrow in human superior maxilla. In this illustration a very large zone of red marrow is shown throughout the centre of the field, and above the tuberosity. The case was edentulous. (Agnew material)

a, red marrow; b, tuberosity; c, floor of maxillary sinus; d, fatty marrow.

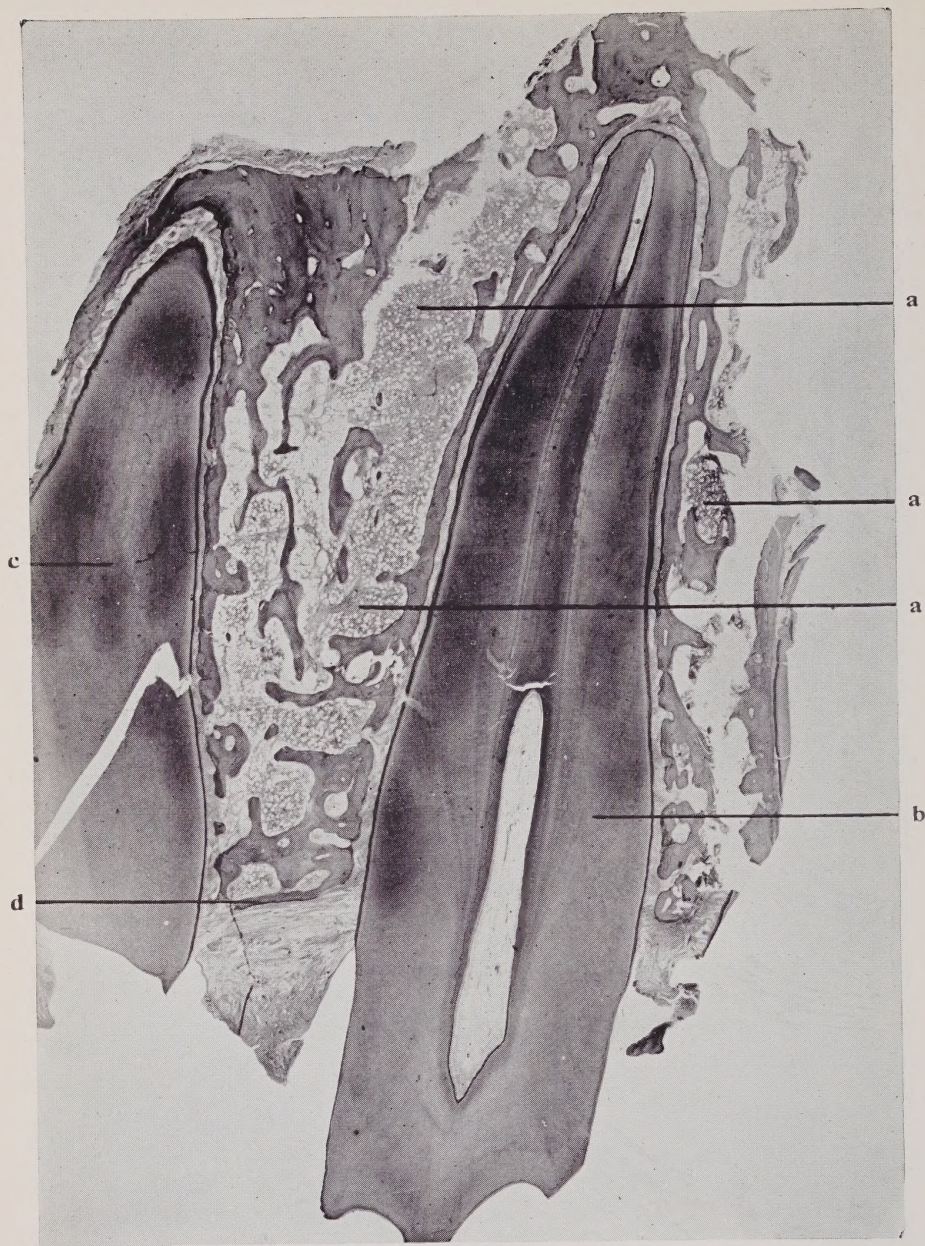


Fig. 5.—Red bone-marrow in human superior maxilla. In this illustration two upper bicuspids are shown. The red marrow is distributed from the crest of the bone to the apical regions.

a, red marrow; b, second bicuspid; c, first bicuspid; d, crest of septal bone.

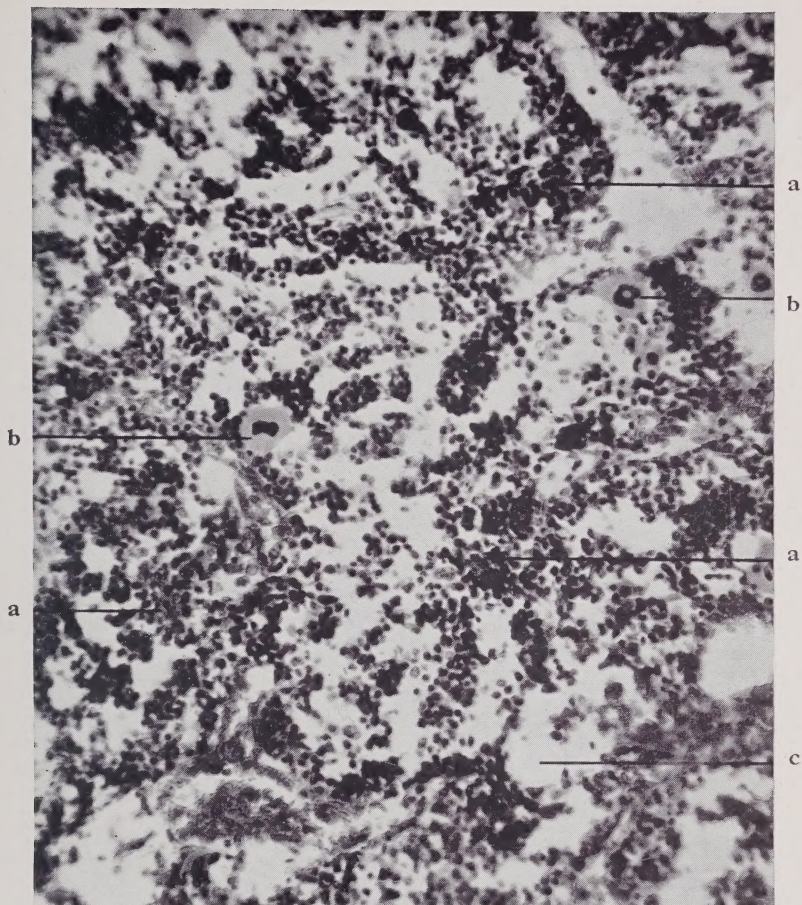


Fig. 6.—Red bone-marrow in mandible of young ground-hog. In this section of fairly high magnification, note the enormous number of haemopoietic cells, and also four megakaryocytes.

a, haemopoietic cells; b, megakaryocytes; c, fat cells.

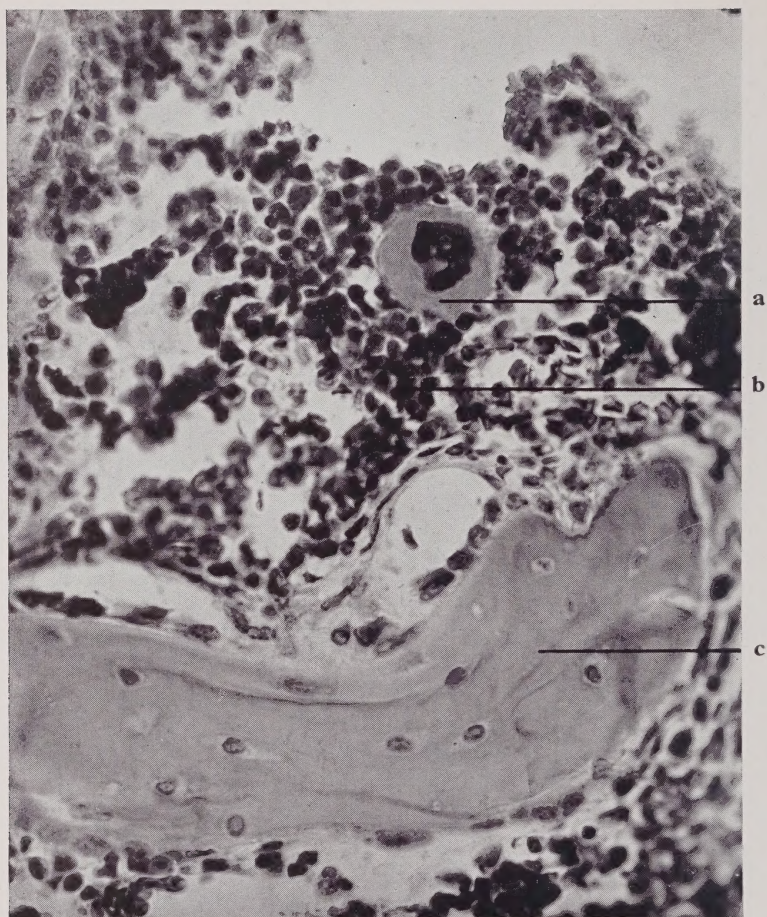


Fig. 7.—Megakaryocyte in red marrow of ground-hog (higher magnification). The megakaryocytes are mononuclear giant cells, and are conspicuous cells of the red marrow.

a, megakaryocyte; b, haemopoietic cells; c, trabecula of bone.

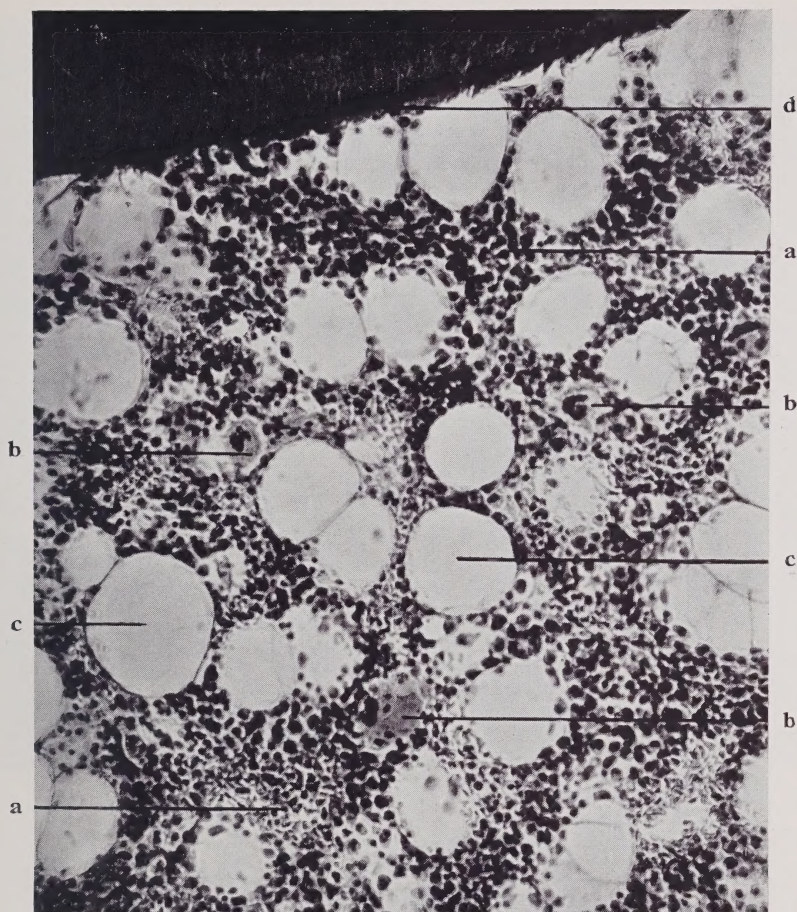


Fig. 8.—Human red bone-marrow showing megakaryocytes. Note the relative amounts of fatty and blood-forming tissue in this section.

a, haemopoietic cells; b, megakaryocytes; c, fat cells; d, bone.

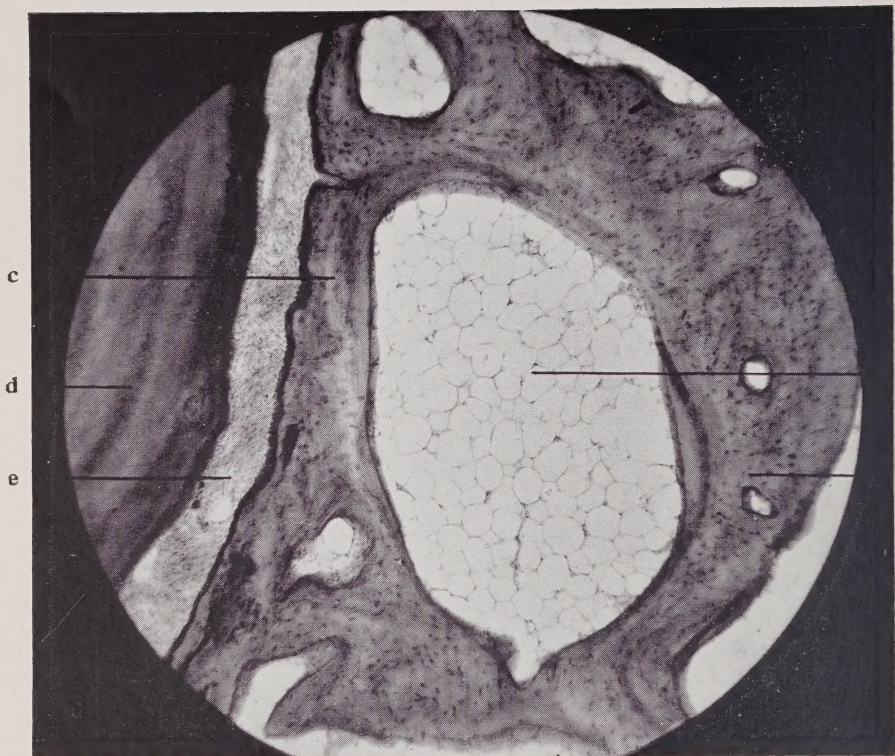


Fig. 9.—Fatty marrow in human mandible. This fairly low magnification shows marrow-spaces containing fatty tissue, and separated in this section from the periodontal membrane by the alveolar bone.

a, fatty marrow; b, supporting bone; c, alveolar bone; d, tooth; e, periodontal membrane.

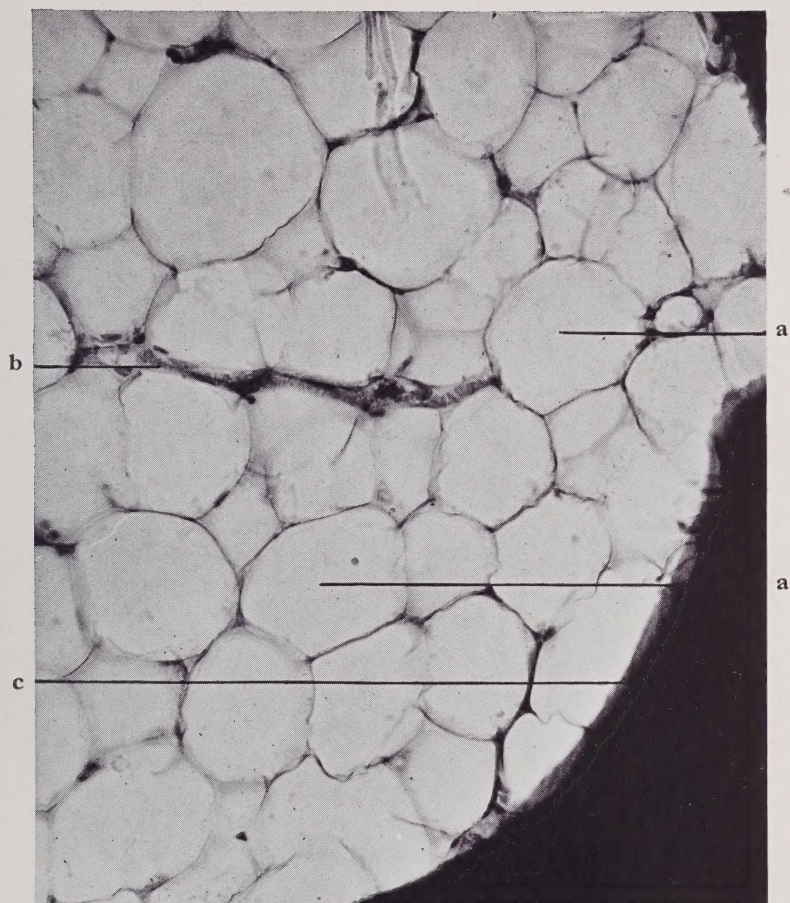


Fig. 10.—Higher magnification of human fatty marrow. Note the sparsity of blood-forming cells in this section.

a, fat cells; b, blood-forming cells; c, bone.

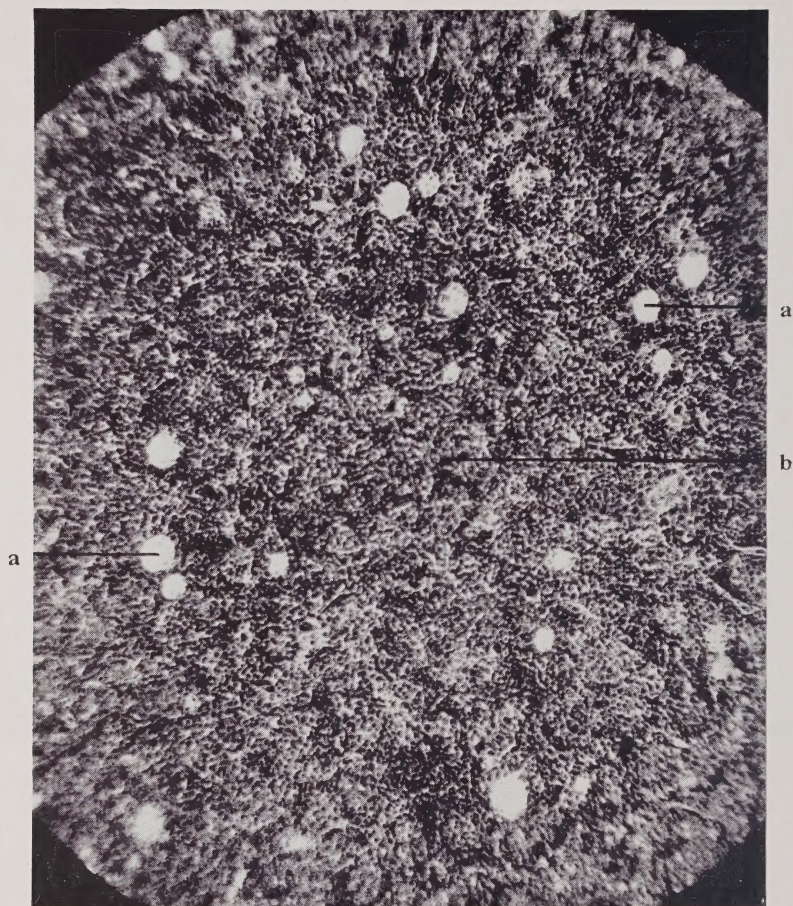


Fig. 11.—Hyperplastic bone-marrow from femur of experimental rabbit in which a pronounced secondary anaemia was produced by repeated bleedings. Note the great diminution in the number of fat cells.

a, fat cells; b, densely packed haemopoietic cells.

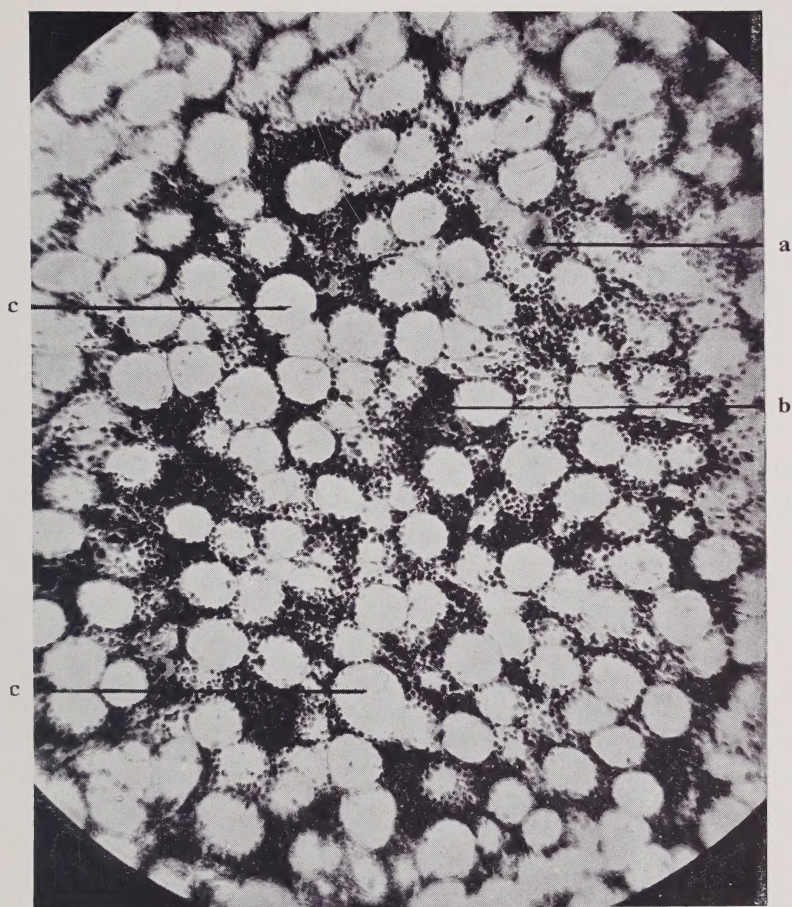


Fig. 12.—Bone-marrow from femur of control rabbit. Note the average normal proportions of fatty and cellular tissue.

a, megakaryocyte; b, haemopoietic cells; c, fat cells.

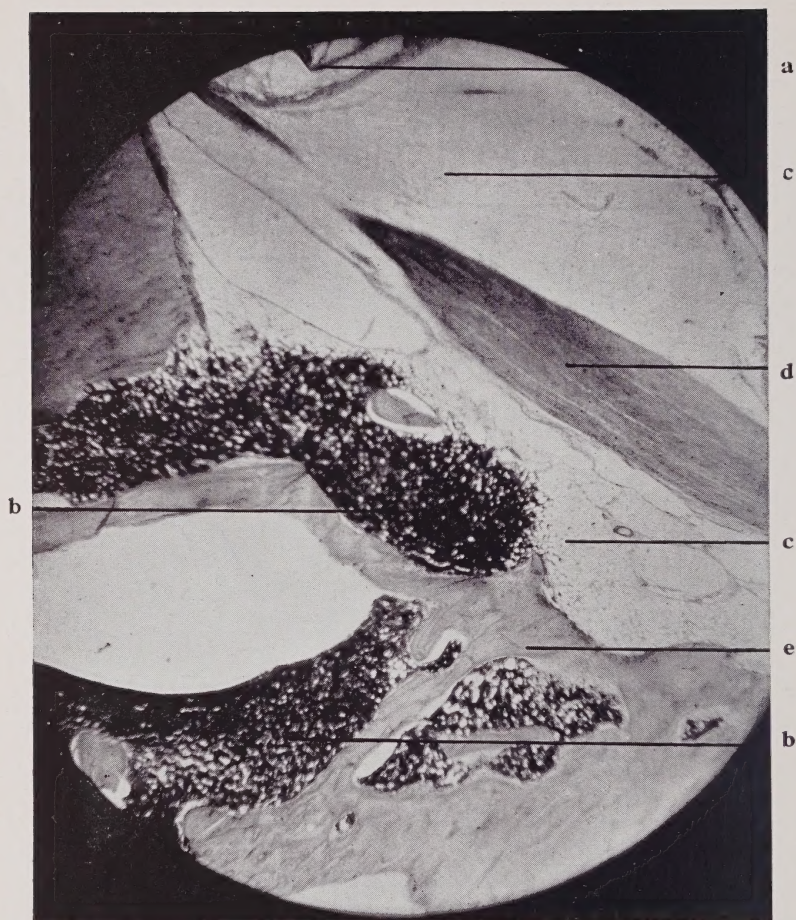


Fig. 13.—Section of mandible of experimental rabbit. Note the zones of hyperplastic red marrow between the trabeculae and beneath the dental nerve, also the adjacent zones of fatty marrow. This field lies directly below the posterior molars.
a, apex of molar; b, zones of red marrow; c, fatty marrow; d, inferior dental nerve;
e, trabecula of bone.

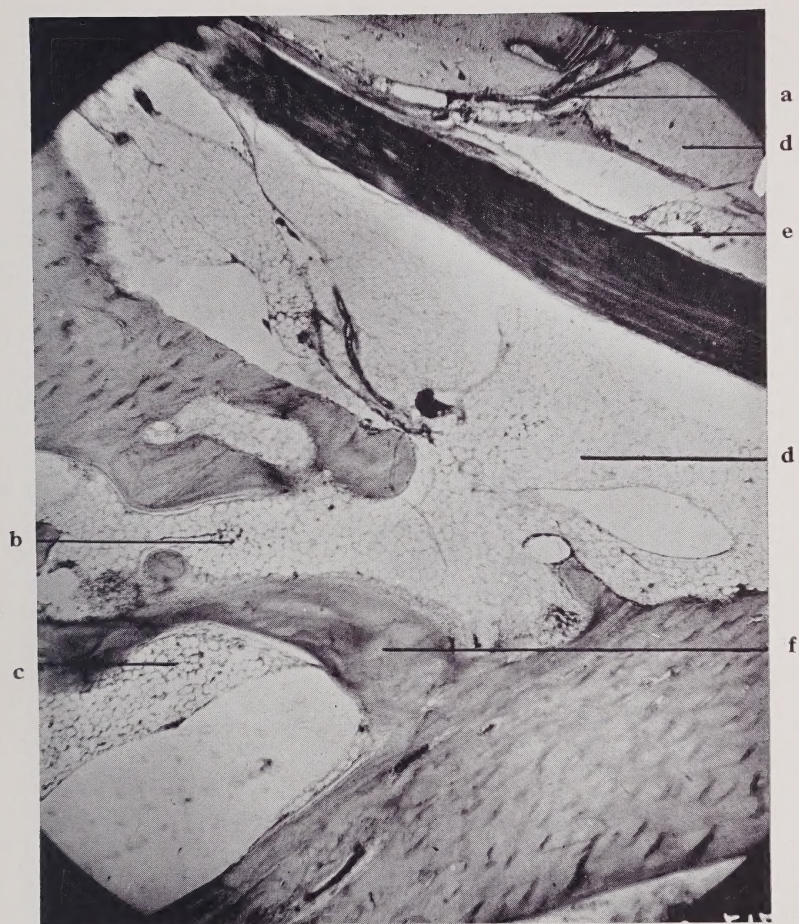


Fig. 14.—Section of mandible of control rabbit, from approximately the same region as Fig. 13. Note the small number of haemopoietic cells.

a, apex of molar; b, small group of haemopoietic cells; c, few scattered haemopoietic cells; d, fatty marrow; e, inferior dental nerve; f, trabecula of bone.

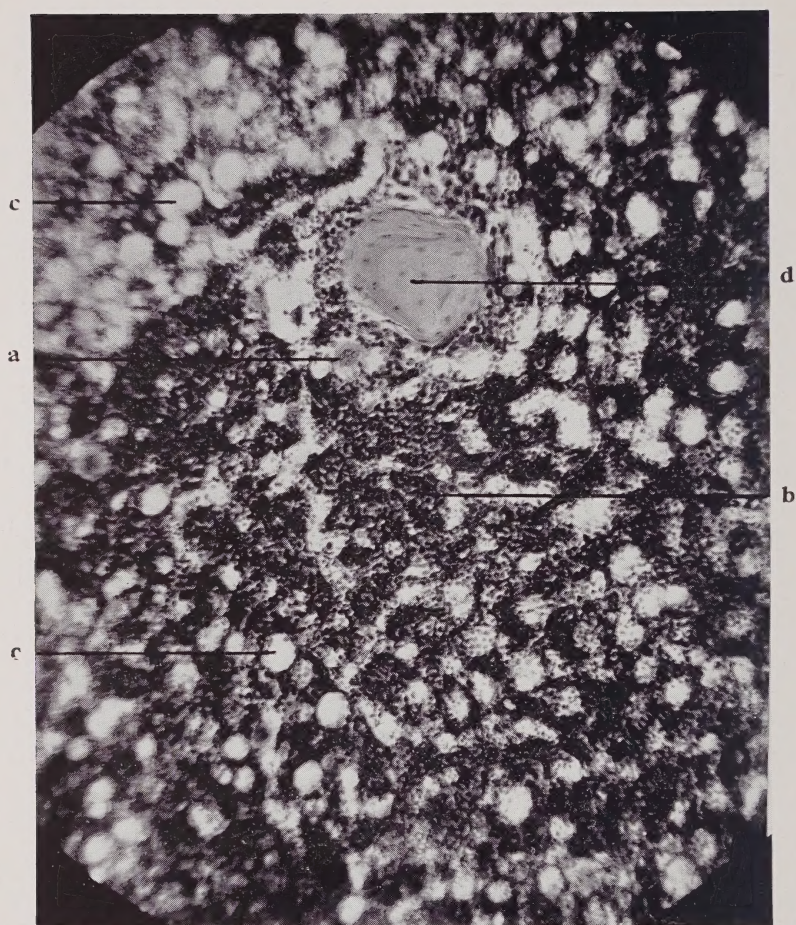


Fig. 15.—Section of malar process of superior maxilla of experimental rabbit. Note the almost complete transformation from fatty into red marrow.

a, megakaryocyte; b, haemopoietic cells; c, fat cells; d, bone trabecula.

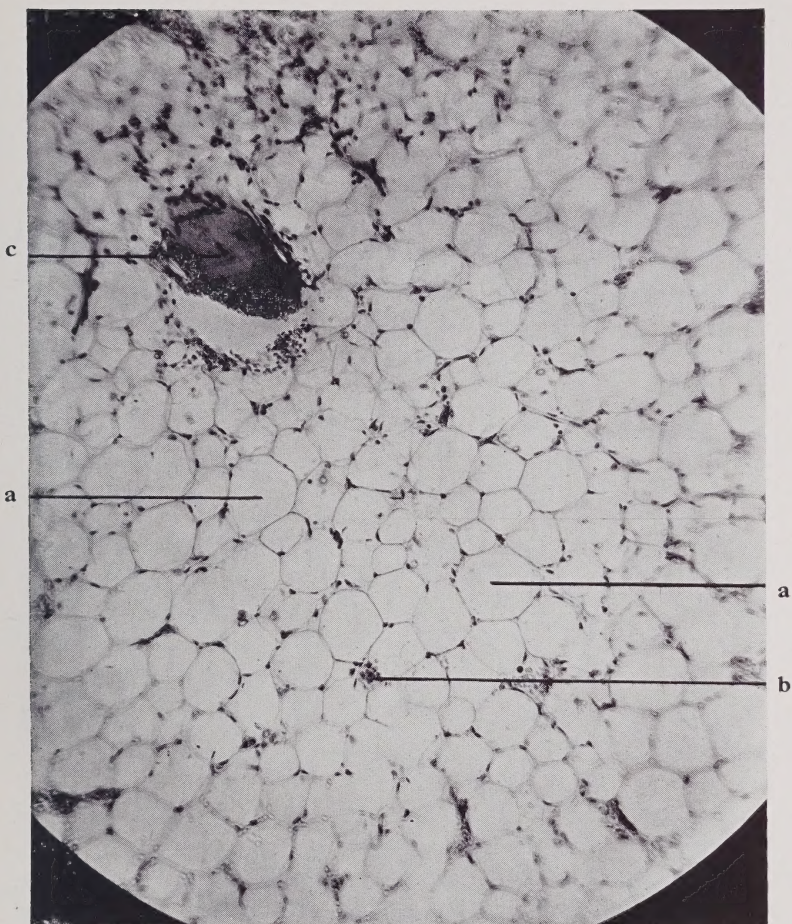


Fig. 16.—Section of malar process of superior maxilla of control rabbit from approximately the same region as Fig. 15, showing normal appearance of fatty marrow with a few scattered blood-forming cells.

a, fat cells; b, haemopoietic cells; c, bone trabecula.

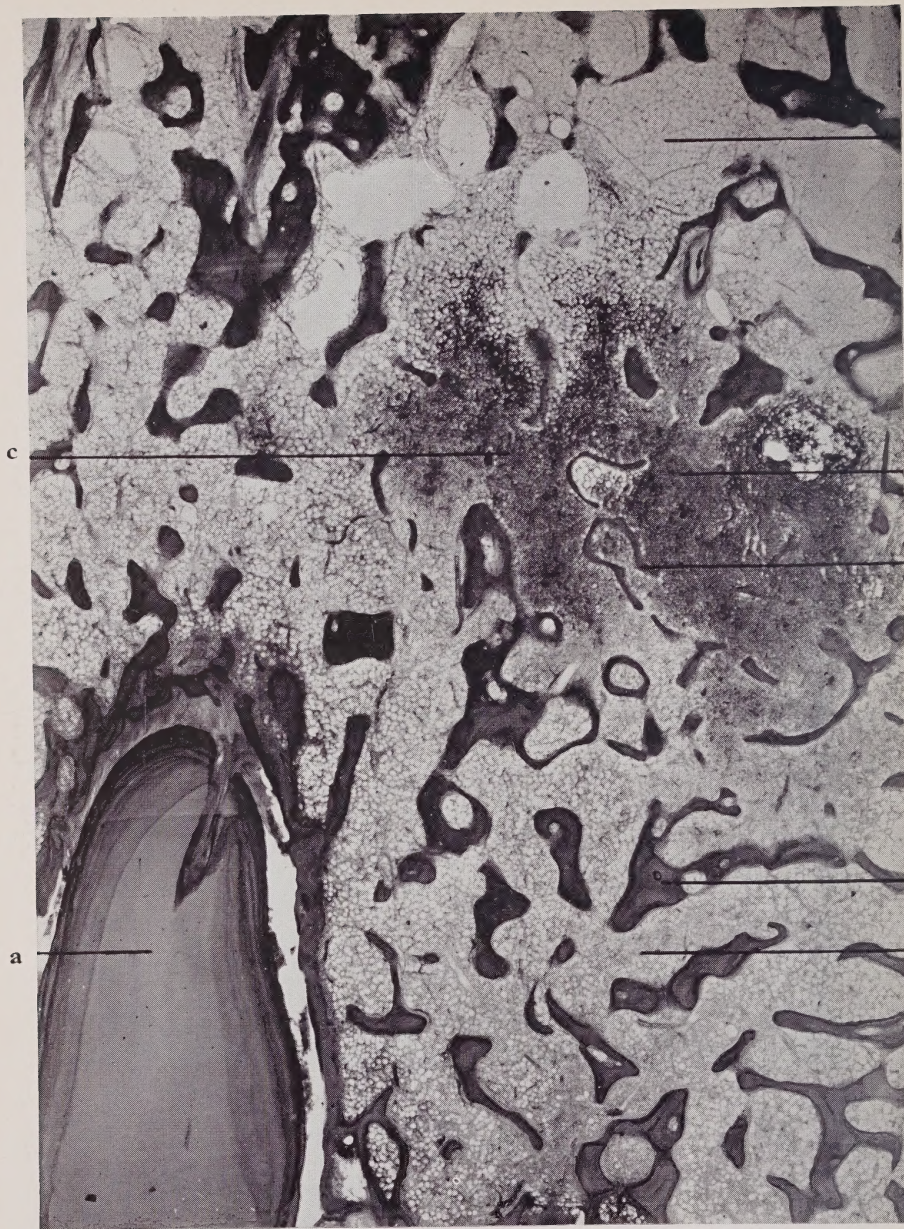


Fig. 17.—Zone of red marrow in human superior maxilla in the region of the root-tips of the lost first molar. Note the apparent hyperplasia of the marrow in this zone, together with the sparsity and smallness of the bone trabeculae, as compared with the trabeculae in the surrounding fatty marrow. (Agnew material).

a, second bicuspid; b, fatty marrow; c, hyperplastic marrow; d, small bone trabecula in red marrow; e, larger bone trabecula in fatty marrow.

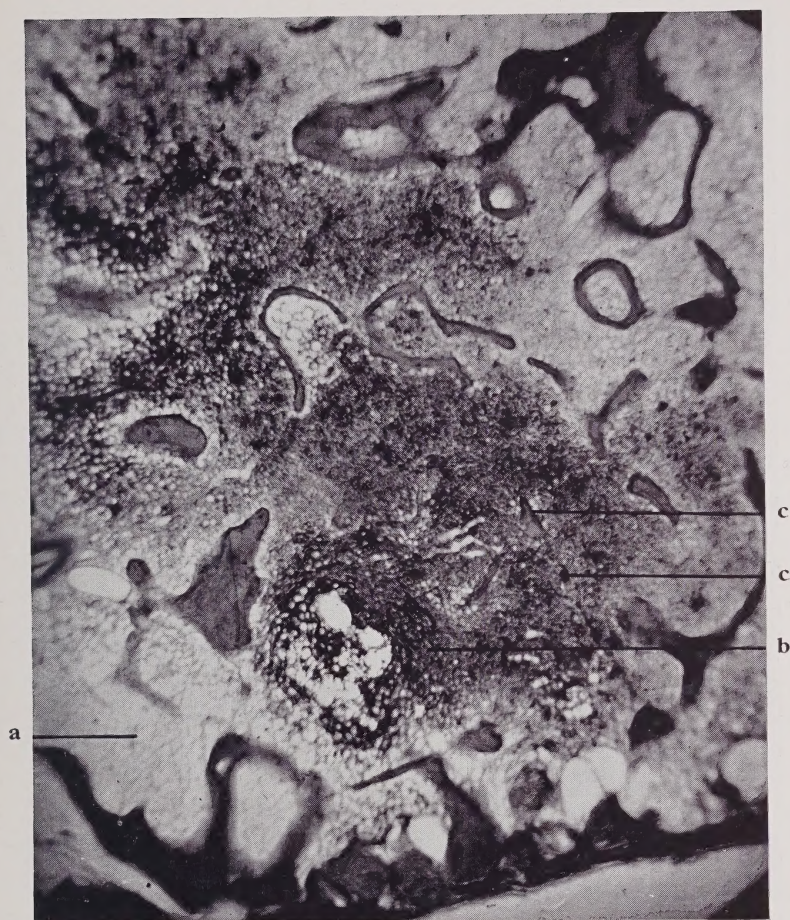


Fig. 18.—Higher magnification from the same zone shown in Fig. 17.

a, fatty marrow; b, hyperplastic marrow; c, small bone trabeculae.

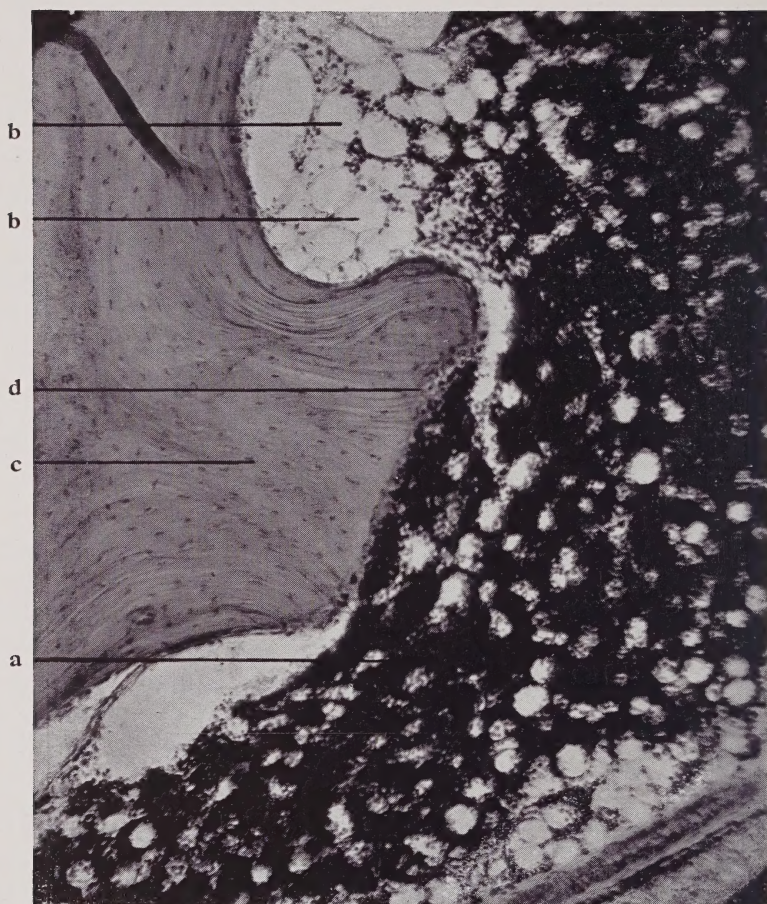


Fig. 19.—Section of hyperplastic bone-marrow from the malar process of the superior maxilla of the experimental rabbit. Note the apparent erosion of the bone in contact with the proliferating haemopoietic tissue.

a, hyperplastic marrow; b, fat cells; c, bone trabecula; d, eroded edge of bone.

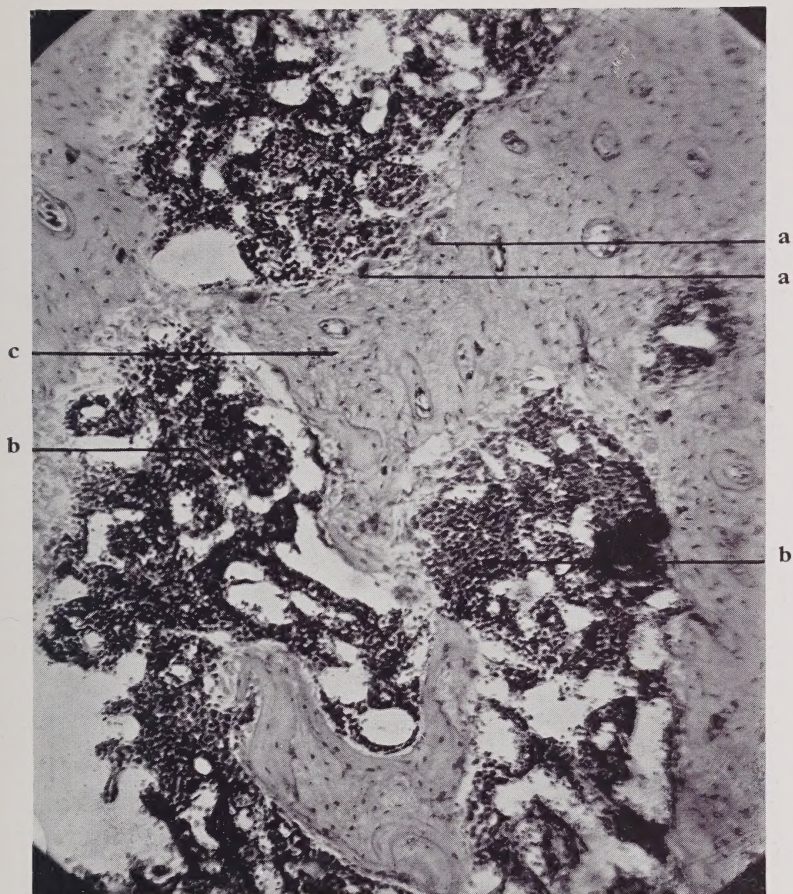


Fig. 20.—Section from the femur of the experimental rabbit. Note the myxomatous appearance of the bony trabeculae, also the numerous osteoclasts, and the hyperplastic marrow.

a, osteoclasts; b, hyperplastic marrow; c, note here the myxomatous appearance of the bone.

Bone Resorption in Red Marrow Hyperplasia in Human Jaws

BY

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S. (ENG.)

*Research Professor of Periodontology,
Faculty of Dentistry, University of Toronto*

BULLETIN NUMBER TWENTY-ONE

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1936

Bone Resorption in Red Marrow Hyperplasia in Human Jaws

BY

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S. (ENG.)

*Research Professor of Periodontology,
Faculty of Dentistry, University of Toronto*

BULLETIN NUMBER TWENTY-ONE

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1936

PRINTED IN CANADA

BONE RESORPTION IN RED MARROW HYPERPLASIA IN HUMAN JAWS

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S. (ENG.)

IN 1933, in a contribution¹ dealing with the subject of red bone-marrow in human jaws, the writer pointed out the need for greater information on the relation of bone-marrow proper to bone proper. Attention was also called to a common and striking feature of this relationship, namely, resorption of the bone of the jaws in hyperplasia of haemopoietic marrow. While the introduction of this specific finding into the field of oral phenomena was apparently original with the publication of that paper, it was pointed out at the time, that its occurrence in general had not been overlooked by other observers.

In 1903, Coats² referred to the atrophy of the lamellae in the shafts of the long bones where the marrow has been increased in anaemias and leukaemia. In 1912, Macewen³ noted that absorption and thinning of the bones occur in certain forms of anaemia. More recently, Beattie and Dickson⁴ have referred to the enlargement of the medullary cavities of the bones, through resorption of the spongy and even much of the compact bone, in pernicious anaemia, and Boyd⁵ has called attention to the same process in the femur and humerus, in pernicious anaemia, and ascribes it to the hyperplasia of the marrow. Beattie and Dickson have also shown gross resorptive changes in the trabeculae of the spongy bone in leucoblastic transformations occurring in the upper portions of the shaft of the femur, associated with acute lobar pneumonia, rheumatic pericarditis and septic peritonitis. And, in a case of chronic septicaemia, they demonstrated partial erosion of the compact bony walls of the medullary cavity of the same bone. Piney⁶ regards the condition of the marrow in chronic myelosis and chronic lymphadenosis as pathological overgrowth, the increase of myeloid tissue being atypical, and essentially not a true hyperplasia. According to this investigator, in chronic myelosis, the cancellous tissue in the long bones is markedly decreased in amount, and slight erosion of the compact bone on its inner surface may occur. In chronic lymphadenosis, certain bones, as a rule the

flat bones, vertebrae and proximal bones of the limbs, show a scanty amount of cancellous bone. Here again there may be distinct thinning of the compact bone.

The evidence of bone resorption in the jaws in marrow hyperplasia, which has become available as a result of our investigations since 1933, in human and experimental material, seemed to justify the following presentation of the more recent developments in the subject.*

It is obvious that a balance normally exists between bone on the one hand and marrow on the other. Disturbance of this balance as revealed in processes of diametrically opposite trends, is well shown in osteopetrosis and red marrow hyperplasia. In osteopetrosis, the bone encroaches on the marrow, the medullary cavity tending to become obliterated. According to Ellis,⁷ "the progressive sclerosis of the long bones gradually reduces the medullary cavity and bone-marrow to a degree incompatible with normal blood formation". A true aplastic anaemia results. In red marrow hyperplasia, manifested in great general demands on the myeloid tissue as in myelosis, certain anaemias and chronic infections, the marrow resorbs and invades the bone.

Hewlett⁸ has presented the following working classification of anaemias:

- I. Anaemia from increased losses of red cells
 1. Anaemia from haemorrhage
 2. Anaemia from blood destruction (toxic, etc.)
 - a. With simple (normoblastic) regeneration
 - b. With pernicious (megaloblastic) regeneration
- II. Anaemias from lessened formation of cells or haemoglobin
- III. Anaemias due to an increase in the blood plasma.

From the foregoing classification it is to be noted that under certain conditions, some anaemias are due primarily to diminished formation of red blood-cells through some failure on the part of the bone-marrow. These are classed together under the term "aplastic anaemia". This type has been produced experimentally in animals by poisons which damage the bone-marrow, *e.g.*, benzol. According to Piney,⁹ in chronic benzol poisoning, "the greater part of the

*The writer is deeply grateful to Arthur W. Ham, M.B., Assistant Professor of Anatomy, University of Toronto, for his kindly aid and encouragement in the study of this problem.

marrow in all the bones is aplastic but it is not surprising that some areas of practically normal marrow remain”.

Under other conditions, anaemias are produced primarily because the red blood-cells, or erythrocytes, are removed or destroyed more rapidly than they are made, *e.g.*, in haemorrhage, lead poisoning, phenylhydrazine poisoning and in pernicious anaemia. Through increased activity on the part of the marrow, in these circumstances more red blood-cells are produced than under normal conditions. Associated with this increased activity is a well-marked hyperplasia of the marrow. With excessive new formation of red blood-cells, the red marrow may extend itself beyond its usual confines and may involve adjacent trabeculae and other bony structures. The factor which causes the bone resorption is the marrow proliferation which is secondary to and induced by the anaemia, and therefore one would not expect to encounter bone resorption in anaemias primarily due to aplasia of the marrow.

The exact stimulus for the new formation of erythrocytes is unknown. As an increased formation of erythrocytes appears to be found in a variety of conditions such as anaemias from haemorrhage and blood destruction, cyanosis accompanying congenital heart disease, life at high altitudes and carbon monoxide poisoning, a diminished oxygen supply to the bone-marrow has been suggested as a possible stimulus. The term ‘anoxia’ has been suggested by Van Slyke to describe oxygen lack in the body from any cause (Wright).¹⁰ The above conditions are representative of at least three types of anoxia, *viz.*, anoxic, anaemic and stagnant. In the anoxic type, the oxygen tension in the arterial blood is lower than normal and in consequence, the haemoglobin is not saturated normally with oxygen, *e.g.*, life at high altitudes, and congenital heart disease. In anaemic anoxia, the oxygen tension in the arterial blood is normal, the anoxia resulting from the decreased amount of functioning haemoglobin, *e.g.*, anaemias from haemorrhage and blood destruction, and carbon monoxide poisoning. In stagnant anoxia, the oxygen tension of the arterial blood is normal but a subnormal amount is supplied to the tissues, *e.g.*, congenital heart disease. It would seem, then, that the bone-marrow reacts to an oxygen lack by increased formation of red blood-cells.

The circulation of the red bone-marrow is characterized by a network of peculiar, thin-walled vessels which are large and intercommunicating. These vessels are called sinusoids, and are lined,

not by common endothelium but by histiocytes or littoral cells (Maximow and Bloom).¹¹ The sinusoids have the capacity of large veins and the blood-flow through them is sluggish, thus making time available for extensive reduction of the oxyhaemoglobin. The oxygen tension in the marrow is low, and this factor, according to Wright stimulates erythropoiesis.

The following experiments were carried out in an endeavour to obtain certain data on the bone-marrow of rabbits, particularly of the jaws, in experimental anaemia produced by haemorrhage. Twelve rabbits in all were taken, six experimental animals and six controls. By repeated bleedings from the ears of the experimental rabbits severe secondary anaemias were produced. All the rabbits were then chloroformed and certain bones including the femora and jaws were sectioned. The fat marrow in certain zones below the molars in the mandibles of the bled rabbits showed a marked replacement by depots of haemopoietic tissue. In these regions, frequent examples of trabecular resorption associated with the hyperplastic marrow were found. Figs. 1, 2, 3.

Considerable human jaw material has been studied in our laboratory, and depots of hyperplastic red marrow have been repeatedly encountered. In these regions, many striking examples of resorption of trabeculae, adjacent to the encroaching hyperplastic marrow have been found (Figs. 4, 5, 6). One example of resorption of the compact bone was seen (Fig. 7). In one case of a human superior maxilla, large depots of marrow adjacent to the alveolar bone and the floor of the maxillary sinus were observed, and marked resorption of these bony structures is plainly evident (Figs. 8, 9, 10, 11, 12). In the same case, numerous examples of trabecular resorption are to be noted (Figs. 13, 14, 15, 16).

The close association between bone and bone-marrow is clearly shown in the fact that in man under normal conditions, marrow is found exclusively in the cavities of the bones. In the embryo and newborn, red marrow occupies the cavities of all bones, but in the normal adult, the red variety has been substituted by the yellow or fatty marrow in all the bones excepting the sternum, ribs, vertebrae, the diploë of the bones of the skull and in the proximal epiphyses of the femur and humerus. The intimate relationship between bone and marrow is further shown in the post-natal development of bone complete with typical bone-marrow in regions far removed from the skeleton. This metaplastic bone formation

is commonly found in the walls of arteries, in the scars of old operation wounds and in the tonsils. The most tenable theory of formation of metaplastic bone explains the phenomenon on the basis of cellular origin from relatively undifferentiated cells in the soft tissues, which, under some stimulus, possibly that of calcium, have differentiated into osteogenic cells, osteoblasts and bone-cells. The relatively undifferentiated cell is probably the undifferentiated mesenchymal cell of Maximow, a cell shown to be of great potentiality. Further, it is probable that the marrow which has developed with the metaplastic bone, has originated from the same cell source. Recent experimental investigations (Maximow and Bloom) in ectopic myelopoiesis,¹² have shown that the myeloid elements may originate from the undifferentiated lymphoid cells which circulate in the blood, the lymphocytes in the lymphoid organs, or the fixed elements of undifferentiated embryonic nature found along the blood vessels.

The question now arises as to the ability of the lining cells of the bone to produce marrow. The bone is covered by a layer of cells on all sides. These cells constitute the inner component of the external membrane of the bone and is known as the periosteum. They also comprise the cellular element of the lining of the Haversian canals, and the cavities of the spongy substance. This thin membrane is known as the endosteum. The lining cells have been termed by Ham,¹³ 'osteogenic cells' in preference to the older designation of osteoblasts. This change in nomenclature was made because of the predisposition of these cells toward cartilage formation under certain environmental conditions. This investigator has demonstrated the capacity of these osteogenic cells to differentiate along either the cartilage or bone pathway, and also into osteoclasts.

According to Adami,¹⁴ "we gain our simplest and most natural explanation of cell differentiation by regarding it as primarily the result of adaptation to modified environment". He pointed out the "fact that cellular structure is the expression of the chemical constitution of the cells", and "that histological alteration presupposes modification in the arrangement and intimate constitution of living matter". A change in properties demands an alteration in the constitution of the substance of the cell. Basically, adaptation implies a rearrangement of the living matter of the cell, and differentiation, therefore, is marked by both structural and func-

tional cellular changes. It is accompanied by specialization for the performance of specific functions with corresponding inability to carry out others. And, as Adami has pointed out, the more pronounced the differentiation of a cell, the less is its capacity to reproduce itself, that is to say, with specialization there is usually a loss in reproductive capacity. Further, under change in environment, there is also shown a loss in histogenetic potentiality.

A splendid example of histological alteration in the cell as it ascends the scale of differentiation is exemplified in the structural differences noted in the undifferentiated mesenchymal cells, the osteogenic cells, the osteoblasts and the mature osteocytes or bone-cells. The undifferentiated mesenchymal cells when compared with typical fibroblasts do not show very distinct structural differences, but in size are always smaller. The osteogenic cells, being representative of the residue of the primitive mesenchyme, while perhaps more limited in their potentiality than the original mesenchymal cells, resemble them. The osteoblasts present more cytoplasm which stains blue in a haematoxylin preparation and are somewhat rounder. Near the nucleus, which is large and contains relatively coarse chromatin particles, a pale attraction sphere with a typical diplosome is usually to be noted. The bone-cells completely fill the lacunae which are usually irregular, and, in general, rounded to oval in shape and the nuclei are large and as a rule, conform in outline roughly with that of the cell.

Modification of environment brings out the histogenetic capacities of a cell. This is well shown in the case of the osteogenic cells, where the evidence shows that in an avascular environment they differentiate to form cartilage, while in a vascular environment, they differentiate to form bone. Indeed, according to Ham, "it is questionable if the development of either cartilage or bone from osteogenic cells is not largely a result of the environment under which the cell differentiates rather than the specific inherent tendency of the cell".

Now let us return to the problem concerning the ability of the lining cells of the bone to produce marrow. In the first place, the evidence shown in the development of bone would indicate this to be the case, and from the periosteal bud. The periosteal bud is the mass of cells, blood vessels and osteogenic cells, which originates in the periosteum and invades the disintegrating cartilage. Secondly, in later life, in the healing of fractures, marrow appears

in the development of callus. And thirdly, as pointed out previously, marrow is also developed in the formation of metaplastic bone. It is possible that in fracture and metaplastic bone, the marrow develops from cells of great potentiality which have migrated into the spaces of the bone. It seems more likely, however, that the marrow was developed from the lining cells of the bone, and which under suitable environmental conditions are able to differentiate along marrow and bone pathways.

It seems highly probable that bone to maintain its integrity as such requires to be covered by lining cells which more or less constantly manufacture the enzyme phosphatase. Robison¹⁵ concluded from his experiments that the production of this enzyme "is a part of those cellular activities which result in the formation of bone." These experiments demonstrate the essential part played by osteoblasts and bone-cells in the calcification of bone through their manufacture of bone phosphatase. Fell and Robison made a study of the correlation between histological differentiation and phosphatase synthesis in embryonic limb cartilage during cultivation *in vitro*. Rudimentary femora, isolated from fowl embryos of 5½-6 day's incubation and cultivated *in vitro* underwent "a remarkably normal anatomical and histological development," and the experiments showed that the increase in the ratio of phosphatase to the dry weight of the femur "corresponded closely with the progress of the histological differentiation, *i.e.*, with the formation of hypertrophic cartilage and periosteal bone." No phosphatase activity was found in small-celled cartilage developed in explants cultivated from the undifferentiated 3-day limb bud mesenchyme.

It is to be noted that the cells in the osteogenic layer on the resorbing bone surfaces adjacent to the foci of proliferating red marrow are not very highly differentiated. If the lining cells, which appear to be of great potentiality, are subjected to environmental influences which tend to stimulate marrow formation in close proximity, one can readily visualize them gradually differentiating into marrow precursors with a corresponding loss of phosphatase production. Through failure of phosphatase formation, with a corresponding cessation of their bone-maintaining function, there would be a coincident melting down of the bone surface.

There is a strong possibility that cessation of the bone-maintaining function of the lining cells may be brought about in another

type of disturbance of the phosphatase mechanism. Normally, this mechanism is believed to create in the matrix a state of supersaturation of the bone salt by hydrolysis of phosphoric ester. The optimum pH of phosphatase was found to be pH 8.4, and the work that has been done on this enzyme has demonstrated that with increasing acidity, there is a decrease in its activity. And, further, under certain conditions, the pH may be optimal, but substances may be present which inhibit the action of the enzyme.

In red marrow, the blood-flow through the sinusoids is sluggish because of their large cross-section. According to Wright,¹⁶ when red cell formation is actively taking place, the blood-flow through the marrow is diminished, thus intensifying the anoxaemia. It is conceivable that with diminution of the circulation rate, accumulation of CO₂ in the marrow tissue occurs with consequent lowering of the pH. The CO₂ diffuses very rapidly through the tissues (Krogh),¹⁷ and with the encroachment of the hyperplastic marrow on the border of the bone, it seems reasonable that in this region, a lowering of the pH of the fluids, including the matrix, would soon take place. With partial or complete inactivation of the phosphatase, the bone-maintaining function of the lining cells, would be inhibited, with resultant erosion of the surface of the bone. It is also probable that the lowering of the pH of the matrix fluid would favour the re-resolution of the bone salts, thus acting as a contributing factor in the resorptive process.

The whole problem of bone resorption in red marrow hyperplasia in the jaws, is replete with fields that are worthy of intensive correlated study and experimental research. This is especially true in the sphere of biochemistry, and in the certainty that more specific information would soon be forthcoming, it is earnestly hoped that such investigations will not long be delayed.

BIBLIOGRAPHY

- ¹Box: Red Bone-Marrow in Human Jaws; University of Toronto Press, 1933.
- ²Coats: A Manual of Pathology; p. 464, Longmans, Green & Co., 1903.
- ³Macewen: The Growth of Bone; p. 23, Macmillan & Co. Ltd., London, 1912.
- ⁴Beattie and Dickson: Text-Book of Pathology; p. 622, G. V. Mosby Company, 1926.
- ⁵Boyd: A Text-Book of Pathology; p. 750, Lea & Febiger, 1932.
- ⁶Piney: Diseases of the Blood; Second edition, pp. 96, 116, P. Blakiston's Son & Co. Inc., 1932.
- ⁷Ellis: Osteopetrosis; Proceedings of the Royal Society of Medicine, vol. XXVII, No. 12, October, 1934.
- ⁸Hewlett: Pathological Physiology of Internal Diseases; D. Appleton and Co., p. 579, 1928.
- ⁹Piney: Recent Advances in Hematology; p. 220, P. Blakiston's Son & Co. Inc., 1931.
- ¹⁰Wright: Applied Physiology; Fifth edition, p. 418, Oxford University Press, 1934.
- ¹¹Maximow and Bloom: A Text-Book of Histology; p. 110, W. B. Saunders Company, 1931.
- ¹²Maximow and Bloom: A Text-Book of Histology, p. 121.
- ¹³Ham: Cartilage and Bone; Special Cytology, vol. II, p. 992, Paul B. Hoeber, Inc., 1933.
- ¹⁴Adami: Principles of Pathology; vol. I, p. 130, Lea & Febiger, 1910.
- ¹⁵Robison: The Significance of Phosphoric Esters in Metabolism; p. 60, The New York University Press, 1932.
- ¹⁶Wright: Applied Physiology; Fifth edition, p. 247.
- ¹⁷Krogh: The Anatomy and Physiology of Capillaries; p. 130, Yale University Press, 1924.

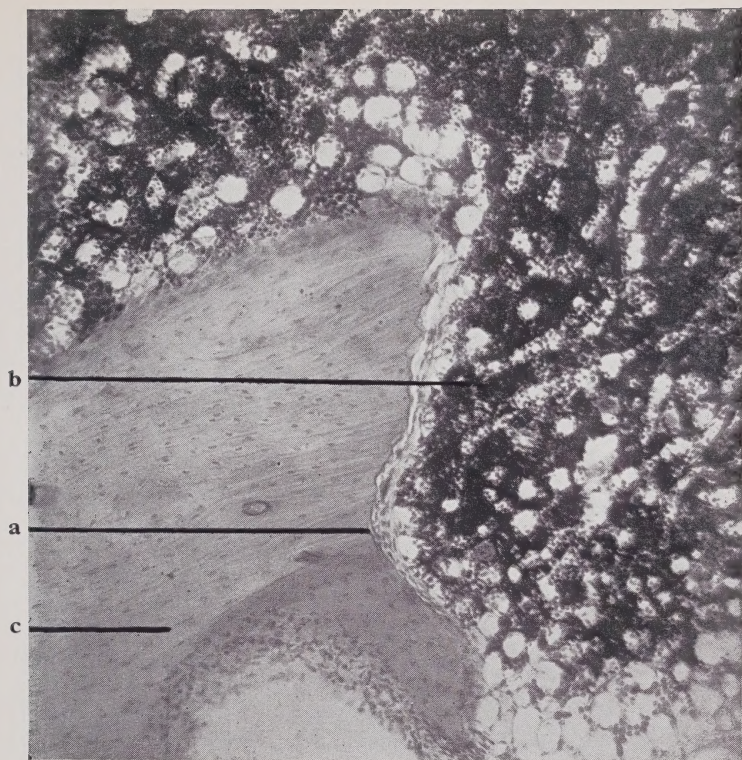


Fig. 1.—Extensive resorption of trabecula and associated hyperplastic red bone-marrow. This section was taken from a marrow depot in the mandible of one of the experimental rabbits. A secondary anaemia was produced by repeated bleedings from the ear.

a, erosion of bone border; b, hyperplastic marrow; c, trabecula of bone.

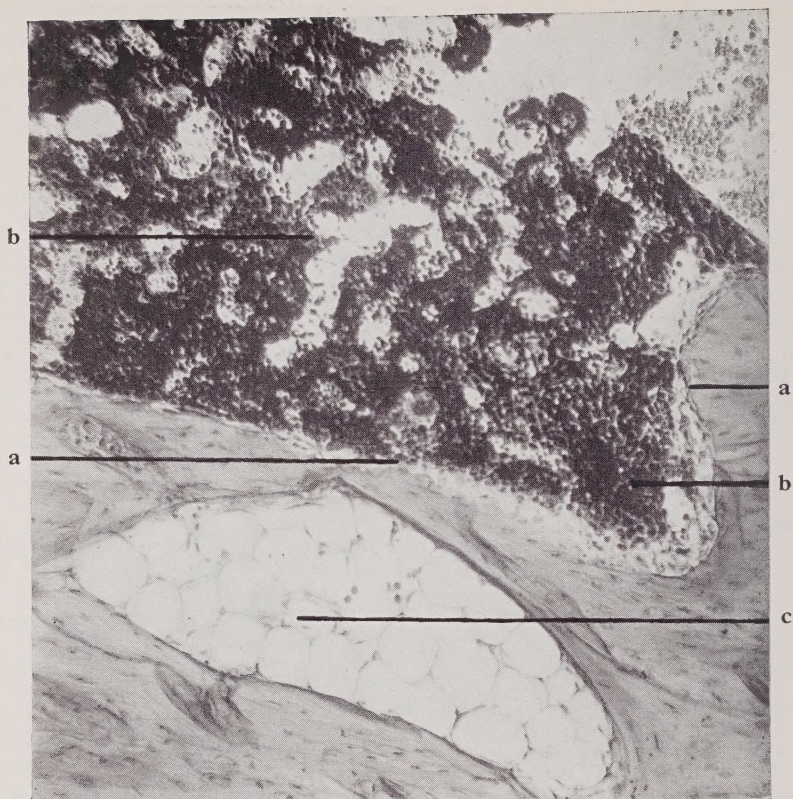


Fig. 2.—Marked resorption of trabecula and cortical bone in red marrow hyperplasia. With thinning of the overlying bone, the hyperplastic marrow is nearing a zone of fatty marrow. This section was also taken from a marrow depot in the mandible of one of the bled rabbits.

a, erosion of bone surface; b, hyperplastic marrow; c, zone of fatty marrow.

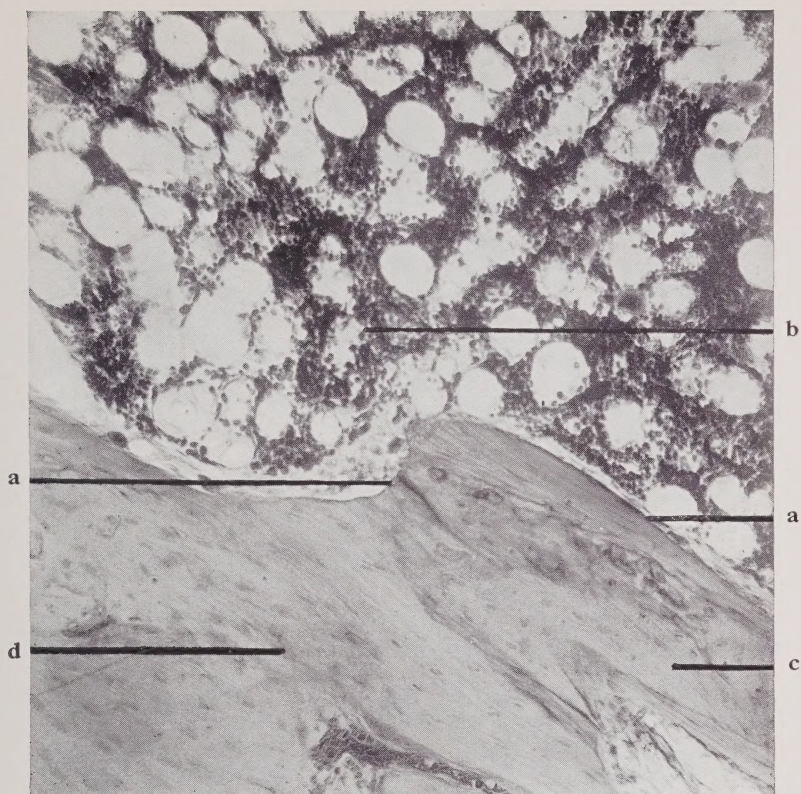


Fig. 3.—Resorption of trabecula in red marrow hyperplasia. The erosion of the bone border adjacent to the proliferating red marrow is plainly shown. The depot of marrow is from the mandible of one of the anaemic rabbits. a, resorption of bone surface; b, hyperplastic marrow; c, trabecula; d, cortical bone.

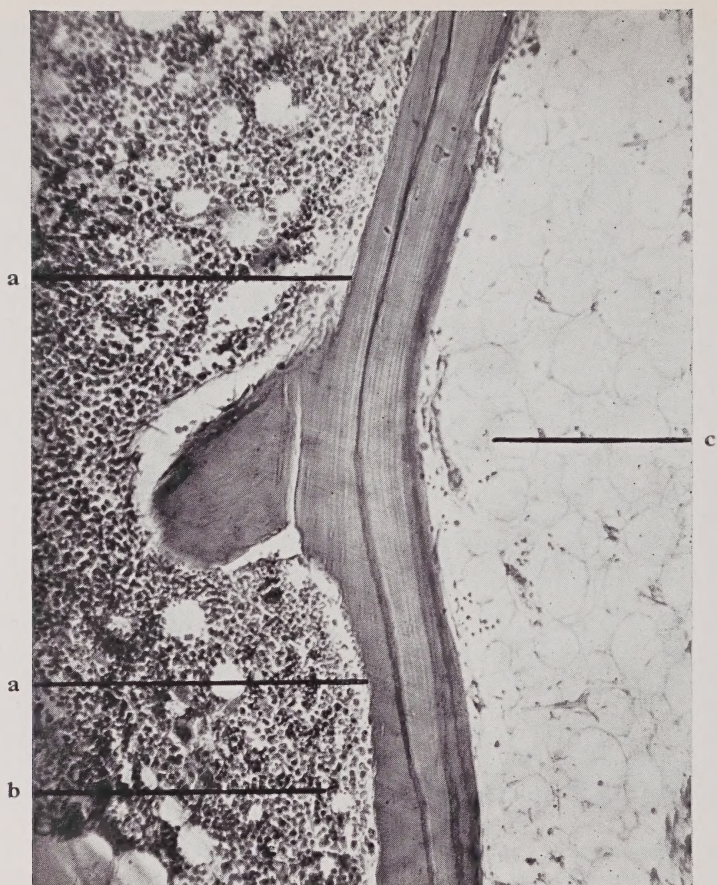


Fig. 4.—Resorption of trabecula of supporting bone, in red marrow hyperplasia. This example was taken from a human superior maxilla. The erosion of the surface adjacent to the hyperplastic red marrow is in decided contrast to the smooth surface contiguous with the fat marrow.

a, eroded bone surface; b, hyperplastic marrow, c, fatty marrow.

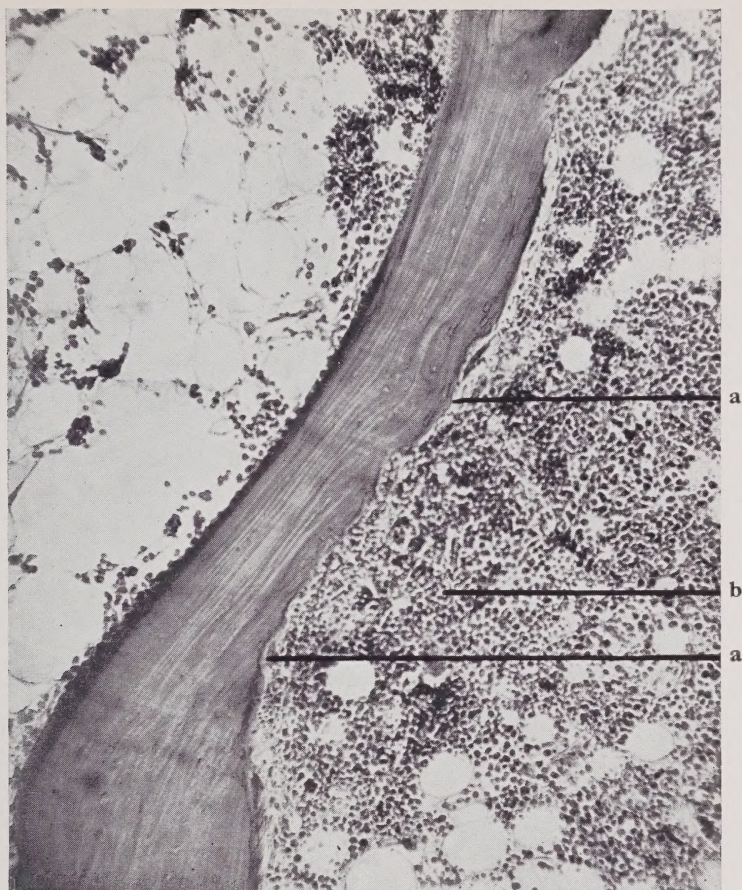


Fig. 5.—Resorption of trabecula of supporting bone in red marrow hyperplasia. This example was also taken from a human superior maxilla; and the same case as Fig. 4. Note the marked erosion of the bone border adjacent to the hyperplastic red marrow.

a, erosion of border of trabecula; b, hyperplastic marrow.



Fig. 6.—Resorption of trabeculae of supporting bone in red marrow hyperplasia. This example is also from the same case as Figs 4 and 5. Note the extensive loss of bony tissue.

a, erosion of bone surface; b, hyperplastic marrow; c, bone trabecula;
d, shrinkage artefact.

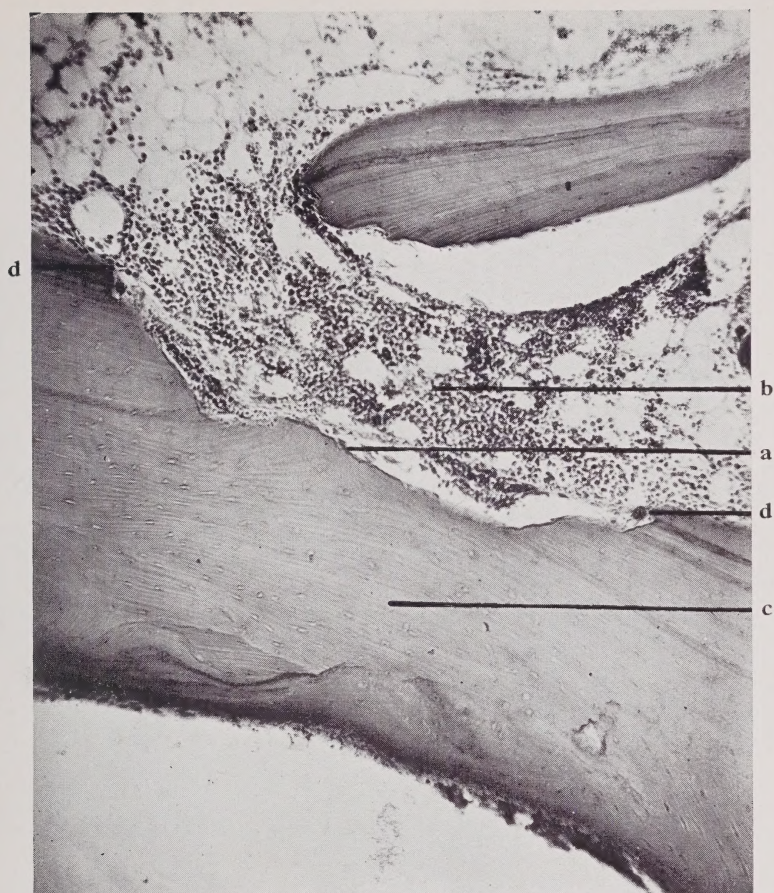


Fig. 7.—Extensive resorption of cortical bone in red marrow hyperplasia. This example is from a human superior maxilla, and the same case as the preceding three illustrations of trabecular resorption. Note the close relationship between the size of the depot of hyperplastic marrow and the extent of the eroded surface of the bone.

a, erosion of bone surface; b, hyperplastic marrow; c, cortical bone;
d, limits of eroded bone surface.

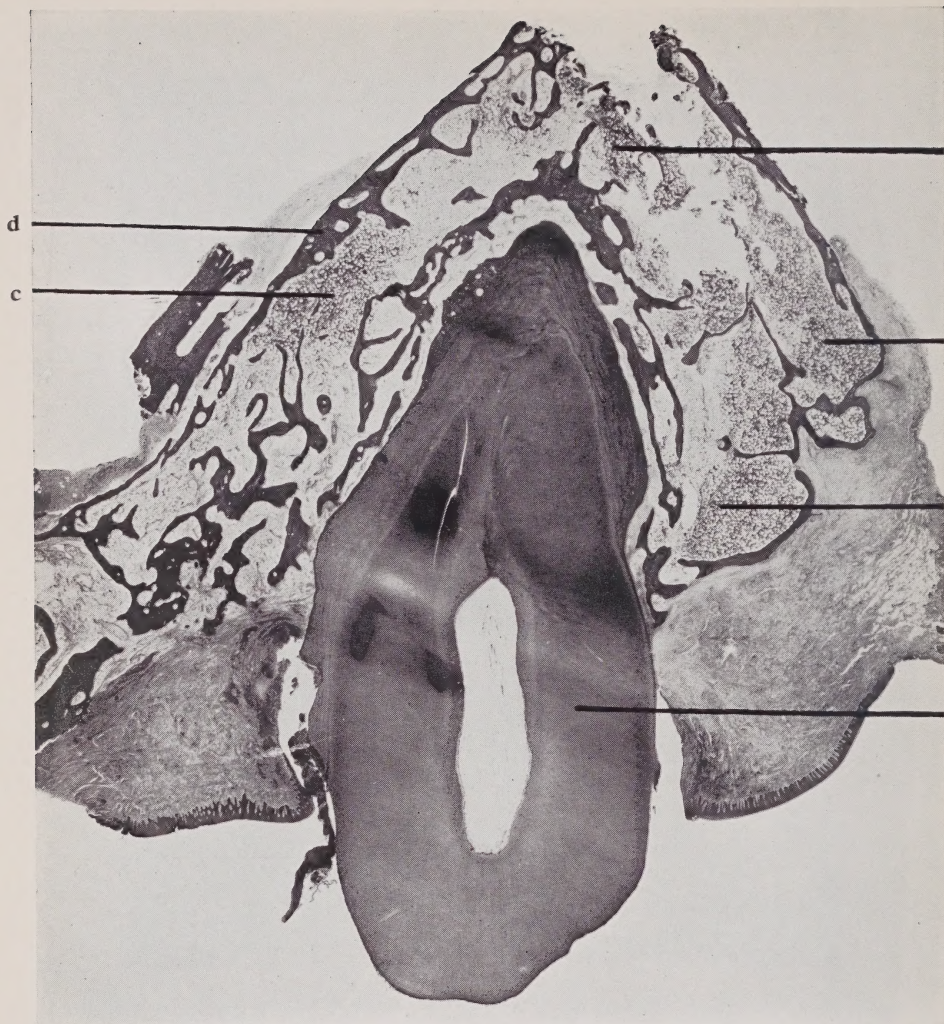


Fig. 8.—Low power photograph of posterior segment of human superior maxilla. The tooth shown in this illustration is the third molar. Note the large depots of hyperplastic red marrow distal to the tooth in the tuberosity and extending upwards beyond the apical alveolar bone. Note also the large zone of hyperplastic marrow beneath the floor of the maxillary sinus and mesial to the tooth apex.

a, red marrow depots in tuberosity; b, red marrow depot beyond the apex;
c, red marrow depot beneath floor of maxillary sinus; d, floor of maxillary
sinus; e, third molar.

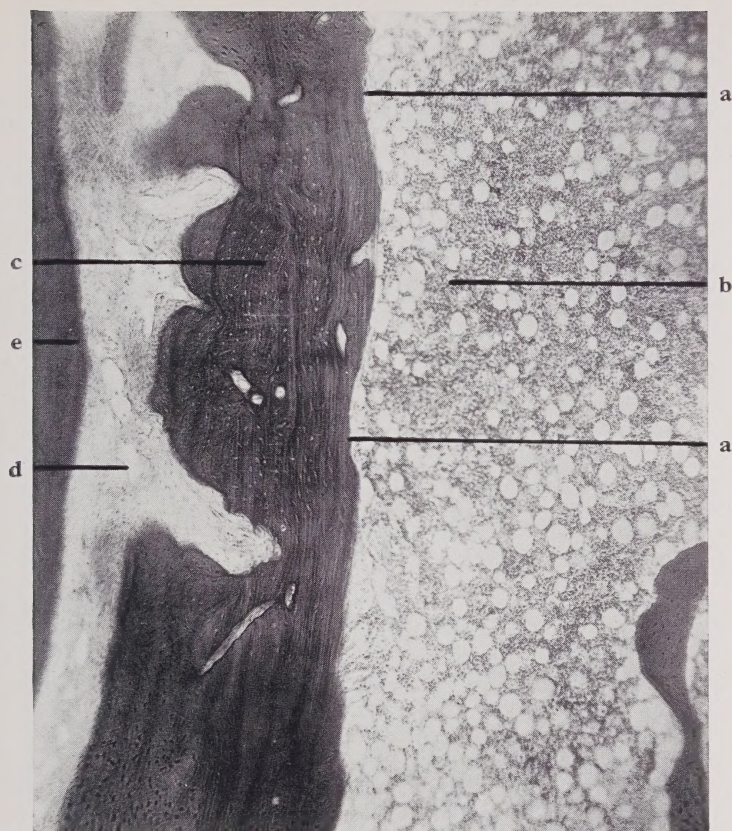


Fig. 9.—Slight resorption of the distal alveolar bone in red marrow hyperplasia. This photomicrograph was taken from one of the sections made from the human case described in Fig. 8.

a, slight resorption on the distal of the alveolar bone; b, hyperplastic marrow; c, alveolar bone; d, periodontal membrane; e, tooth.

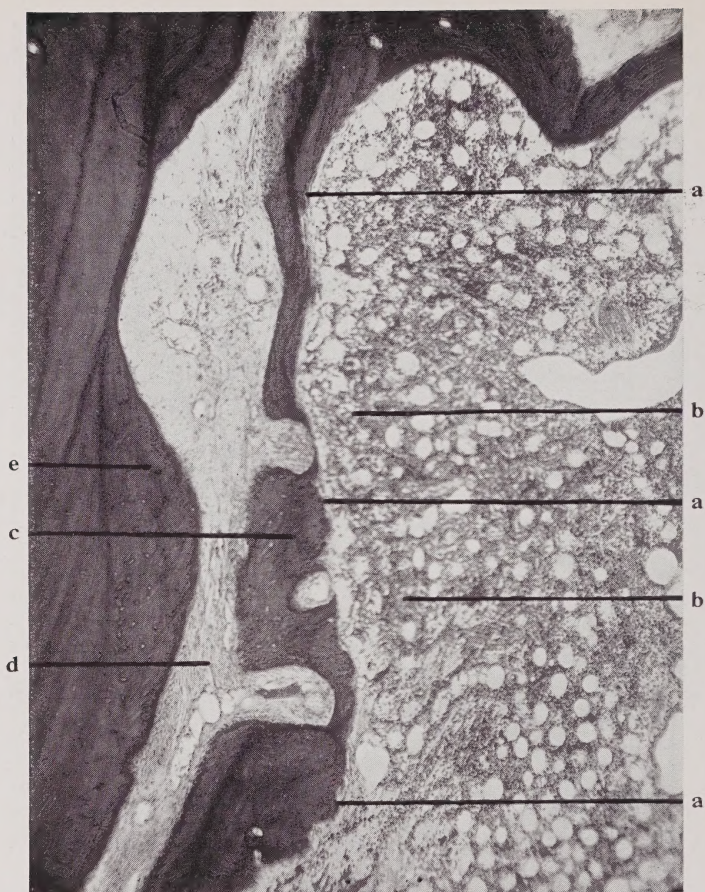


Fig. 10.—Extensive resorption with marked thinning of the distal alveolar bone, in red marrow hyperplasia. This example is also from the human case described in Fig. 8.

a, marked erosion of distal alveolar bone; b, hyperplastic marrow; c, alveolar bone; d, periodontal membrane; e, tooth.

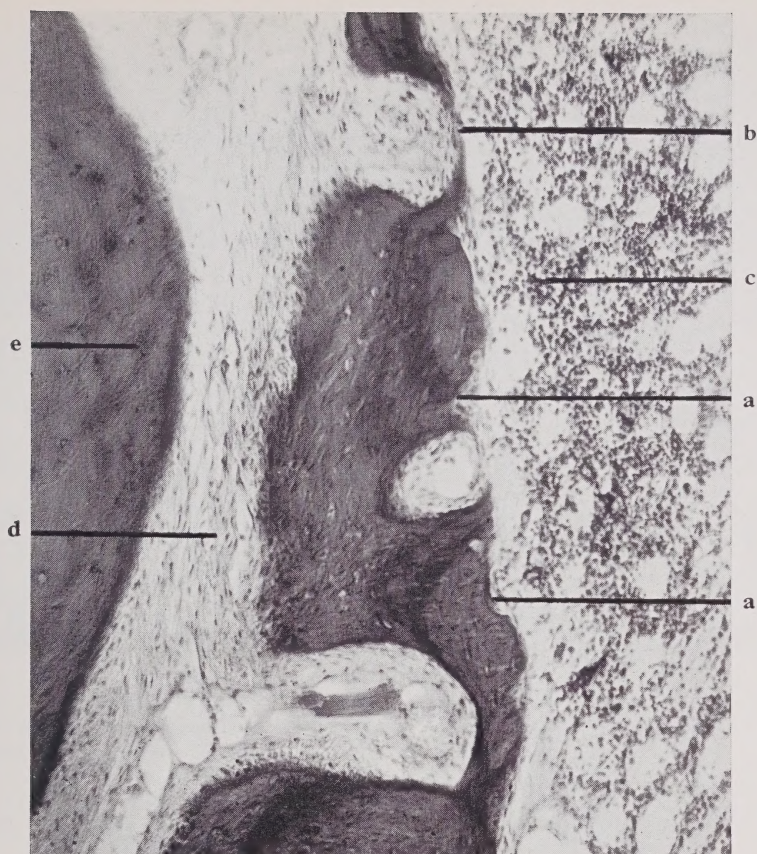


Fig. 11.—Higher magnification of a field from the preceding section. This illustration clearly shows the erosion on the distal surface of the alveolar bone, and the distinct thinning of this structure.

a, erosion of alveolar bone surface; b, extreme thinning of alveolar bone;
c, hyperplastic marrow; d, periodontal membrane; e, tooth.

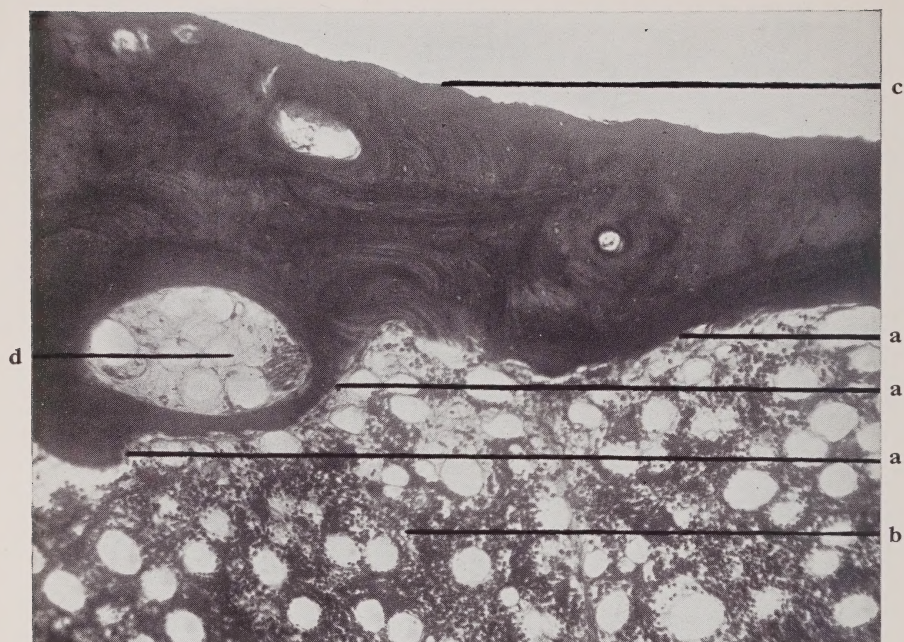


Fig. 12.—Extensive resorption of the lower surface of the bony floor of the maxillary sinus, in red marrow hyperplasia. Note the eroding process thinning the bone over a zone of fatty marrow. This example was taken from the human case described in Fig. 8.

a, marked erosion of lower surface of floor of maxillary sinus; b, hyperplastic marrow; c, upper surface of the floor of maxillary sinus;
d, small zone of fatty marrow.

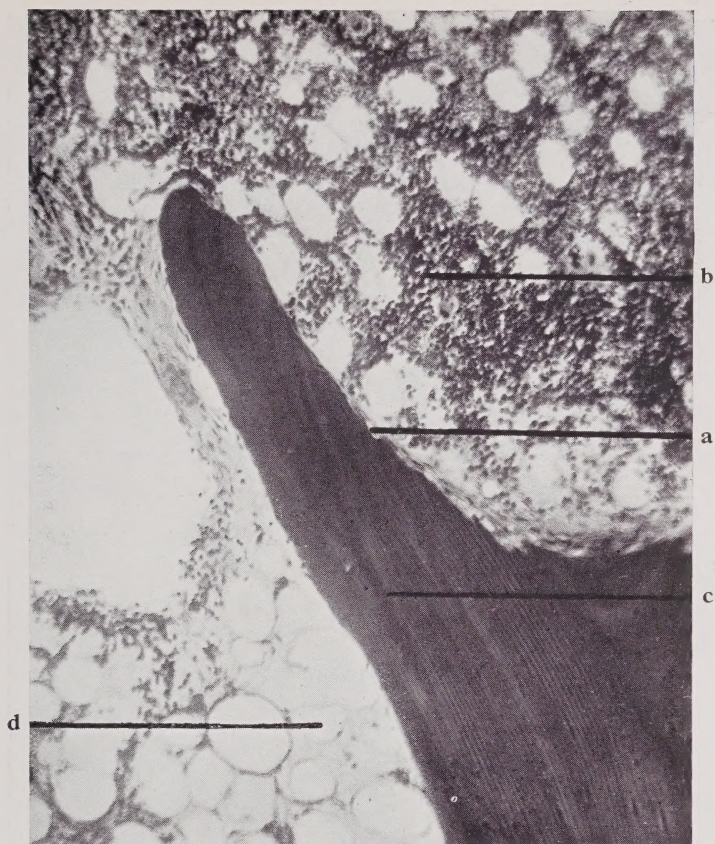


Fig. 13.—Trabecular resorption in red marrow hyperplasia. The eroded surface is in sharp contrast to the smooth bone border adjacent to the more fatty marrow. This example, together with those following, was taken from the human maxilla described in Fig. 8.

a, eroded bone edge; b, hyperplastic marrow; c, bone trabecula; d, fat.



Fig. 14.—Trabecular resorption in red marrow hyperplasia. The erosion of the surface of the bone adjacent to the hyperplastic marrow is again in sharp contrast to the smooth surfaces in contiguity with the fat marrow.
 a, erosion of bone surface; b, hyperplastic marrow; c, bone trabeculae; d, fat cells.



Fig. 15.—Trabecular resorption in red marrow hyperplasia. In this illustration, two large zones of hyperplastic marrow are shown, with distinct erosion of the neighbouring bone surfaces.

a, eroded surface of trabecular bone; b, hyperplastic marrow.

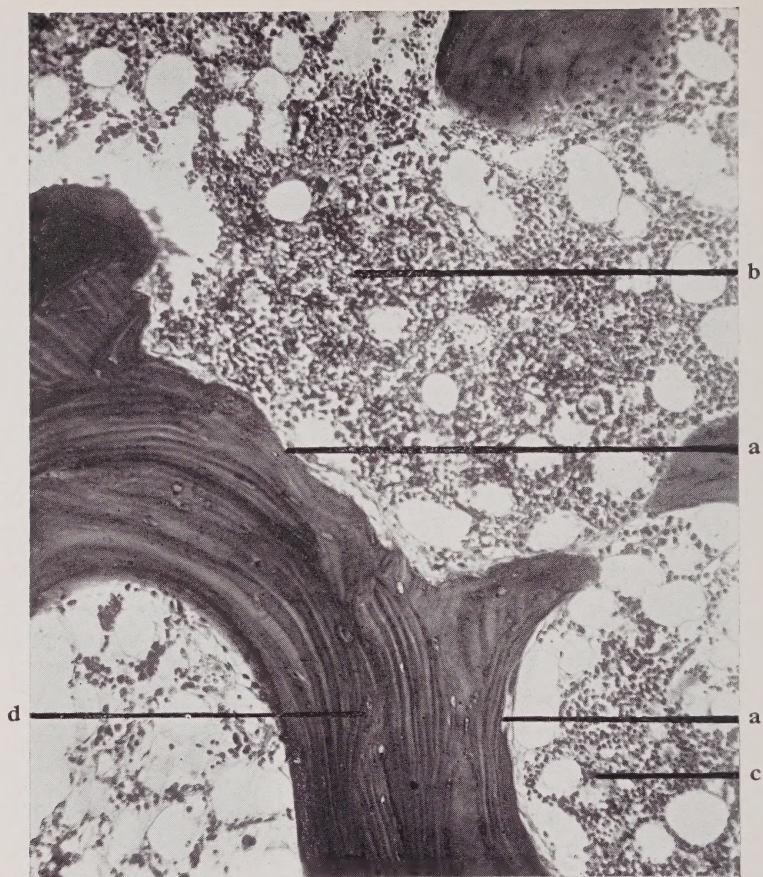


Fig. 16.—Trabecular resorption in red marrow hyperplasia. Note in this illustration, the extensive resorption of the bone edge adjacent to the large zone of hyperplastic marrow. Also, erosion is apparent in the smaller zone of hyperplastic marrow in the lower right corner of the picture.

a, erosion of trabecular surface; b, large zone of hyperplastic marrow;
c, small zone of hyperplastic marrow; d, bone trabecula.

A Theory of a Mechanism Concerned in Tooth Extrusion

BY

A. F. FENTON

Research Technician, University of Toronto

AND

D. P. SUTTON, D.D.S.

BULLETIN NUMBER TWENTY-TWO

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1936

A Theory of a Mechanism Concerned in Tooth Extrusion

BY

A. F. FENTON

Research Technician, University of Toronto

AND

D. P. SUTTON, D.D.S.

BULLETIN NUMBER TWENTY-TWO

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1936

PRINTED IN CANADA

A THEORY OF A MECHANISM CONCERNED IN TOOTH EXTRUSION*

By A. F. FENTON, *Research Technician, University of Toronto*
and D. P. SUTTON, D.D.S.

CONTINUOUS shedding at the surface of the epidermis is a familiar process characteristic of all stratified squamous epithelium. This loss at the surface is continuously being compensated for by addition of new cells in the deeper, germinative layers of the epidermis. An attempt will be made to show that this procession of cells outward to the surface constitutes a force for the extrusion of not only the epithelial cells of the skin proper but also for all structures in the building of which the epithelium takes a direct part. In the human these structures include hair, nails and teeth.

INVAGINATION, FORMATION, EXTRUSION

In the formation of appendages the procedure adopted by the epithelium is as follows:—first, invagination of the connective tissue; then, in collaboration with the connective tissue the epithelial cells enter actively into the building of structure; the final step is the outward extrusion of epithelial cells to the surface with the structure attached. This is essentially a continuous procession. Each phase of this cycle, *i.e.*, ingrowth, formation, and extrusion, is distinctive and marked by different activities on the part of the cell, yet all phases are so interrelated that they constitute a mechanism with a special extrusive function. The activities and behaviour of the epithelial cells in their inward growth, and also in their outward passage, are essentially the same in the case of each of the appendages. In the formative phase, however, this is not the case. The nature of the appendage is determined here; the variations in form and constitution being governed by the relative parts taken by the epithelial cells and the connective tissue.

In the invagination phase of the cycle the ingrowth takes the form of a more or less cord-like body of cells which terminates at

*From the Department of Periodontal Research, Faculty of Dentistry, University of Toronto.

a point where, in conjunction with the connective tissues the appendages are formed. The progress inward of the epithelial cell mass is accomplished by the addition of new cells at the innermost points of the ingrowth, and, at a greatly accelerated rate over that of normal growth. Primarily it is simply a multiplication of epithelial cells, which, during their invasion of the connective tissue, maintain continuity with the surface epithelium. For more detailed description of this development the reader is referred to text-books on histology.

The second phase—that of formation of structure, has been touched upon briefly above. Here it need only be noted that the specific nature of the associated connective tissues in the different cases, must be responsible for the varied activities of the epithelial cells, and also for the formation of intermediary structure which is prominent in the case of the teeth. It is not our intention to imply a homogeneity of the hair, nails, and teeth, but rather to indicate the principle of force development apparent in the extrusion of the epithelial cells proper, the force which makes possible the final step in the procession, *i.e.*, extrusion. A brief outline of the histology, and physiologic processes of squamous epithelium will here be in order, with especial reference to the gingival epithelium.

GROWTH PROCESS

In reviewing the growth processes of epidermis as enunciated in standard works we find the epithelium of the gingivae classified as stratified squamous so that in mode of growth and final desquamation the gingival epithelium behaves the same as all epidermis of the body. According to Cowdry¹ the epidermis structurally is made up of an avascular sheet of epithelial cells tightly bound together, varying in thickness depending upon local conditions. The deeper layers are living, and through multiplication and displacement toward the exterior, compensate for the loss of dead cells from the surface. The innermost cells are arranged in a single layer of basal or germinative cells and are columnar in shape. Passing outward toward the middle of the germinative layer the cells first become more rounded, and then flattened in a direction parallel with the surface. At the same time there is a development of intercellular bridges. The cells are held firmly together by these intercellular processes which appear to be organic continuations of the cytoplasm between neighbouring cells.

The cells just outside of, or above the germinative layers are older and differ from the younger and underlying ones in the loss of old characteristics and in the development of new properties. Normally these cells do not multiply. The formation of keratohyalin occurs in this layer, appearing first as droplets or granules; later, toward the outer layer the cell walls become stiffer with keratin, until at the outermost layer, the stratum corneum, the cells are dead and rigid with keratin. No satisfactory explanation of keratinization has ever been advanced. In normal epidermis this process becomes more and more marked as the periphery is approached, with the following physico-chemical changes noted:

- (a) Decrease in water.
- (b) Lowering of pH.
- (c) Increase in keratohyalin to a maximum from the basal layers outward through the cells to a point where keratin itself is formed.

In discussing the mode of growth of epidermis, Smith² describes it as follows: The normal cell division in the basal layer is a differential division, a basal cell divides into two. One of the new cells remains a basal cell, the other becomes a polyhedral or prickly cell. The polyhedral cell has an angular shape different from that of the columnar basal cell. It also forms connecting bonds with its neighbours, the intercellular bridges; and each cell is separated from its neighbour by a narrow channel, crossed at intervals by these intercellular bridges. The polyhedral cells still continue to divide, though they are differentiated. The polyhedral cells so formed occupy the outer part of the stratum germinativum. They are gradually moving outward and on the outer border they assume a form flattened parallel to the surface of the skin. They accumulate granules of differentiated substances, keratin and eleidin, and become the stratum granulosum. These cells are, in turn, transformed into clear structures. The nucleus has disappeared; the granules are fused; the layer is homogeneous and the cells hardly to be distinguished from each other. The final transformation occurs when the elements of the outer layer become dry keratin scales still firmly glued to the surface, but later to fall off.

The above is descriptive of the classical picture of stratified squamous epithelium. The gum epithelium however does not conform strictly to this marked stratification, or division into layers.

The mode of growth and passage outward of the cells, with final desquamation are, nevertheless, the same as in all epidermis. Thus in the gum epithelium the keratinization and drying of the cells are more evenly progressive processes than is the case with most epidermis, especially that subjected to friction and drying.

EPITHELIAL EXPANSION

The method of addition of cells in the basal layers of squamous epithelium is one which must inevitably add to the mass of the tissue were it not for the shedding compensation at the surface. When a basal cell, on the layer directly in contact with the connective tissue divides in normal maintenance of tissue, one daughter cell becomes a differentiated cell and joins the ranks of the polyhedral cells inside, while the other daughter cell remains a basal cell and maintains the position of the parent cell. When a polyhedral cell divides both daughter cells are polyhedral or prickle cells. In such normal maintenance it is suggested that the rate of division in the polyhedral layers far exceeds that at the extreme basal layer. It seems probable that the cells immediately adjacent to the connective tissue source of nourishment act somewhat in the capacity of secretory cells. As such they do not ordinarily divide. Their columnar shape would seem to support this view. The inner or polyhedral cells divide more or less continuously however, and the polarity of these cells indicates that always one daughter cell progresses outward toward the surface while the other maintains the position of the parent cell (Figs. 1, 2, 3). Huxley³ describes the movement outward as "a thrusting away by the intercalation of new cells between the last formed and the progenitors."

When epithelium invades the connective tissues, *e.g.*, in development of the primordium of an appendage, the surface area of the epithelium contiguous to the connective tissue is increased by the division of cells of the basal layer as well as by those above. In this case, when these basal cells divide, the polarity of the dividing cells is parallel with the connective tissue as in normal growth, but the two daughter cells remain at the periphery of the ingrowth side by side. Thus the surface area is increased and the aggregate mass becomes greater. So it appears that in the case of ingrowth the addition of new cells results in the propulsion of the epithelium as a body toward, and into the connective tissues; while, in ordinary growth on the other hand, the addition of new cells is continuously

directed away from the connective tissues, or, toward the surface, and thus the propulsion of the epithelium as a body, is directed outward. It is seen that the movement of the cells outward cannot be achieved by the cells individually except in the deeper, germinative layers, as the cells above these are tightly bound together. The movement is then a mass extrusion; the outer tightly bound body of the epithelium undergoes gradual expulsion. It is difficult to find a simple analogous illustration of this mass movement, but perhaps it is self evident that the individual cells are found eventually at the surface in a stiffened, non-vital state not through their own volition during the latter part of their passage outward, but because they have become immobile segments of an outward moving mass.

HAIR

In the moulting of hair which is a normal process in man, the principle of mass movement of epidermis is well demonstrated. In describing the shedding of hair Jordan⁴ states: "The shedding of hair is first heralded by the atrophy of its papilla and cornification of its bulb, growth ceases and the hair, firmly adherent to its root sheath, is gradually carried by the continued growth of the latter nearer and nearer the surface of the skin." The root sheath is made up of epithelial cells which are continuous with the surface epithelium. As the older cells of the root sheath epithelium are extruded toward the surface, the hair, being tightly bound to them is also extruded. The same force however is in operation in the case of living hair, with the difference that in the formative phase the propulsive force of structure development is in full activity also. Thus the formative process may or may not be in the procession, but the growth of the epidermal sheath and the extrusion of epidermal sheath cells are constant features. That is to say, it is clearly the work of the upper epidermal cell-body, then, to supply an auxilliary force for extrusion of the hair during the formative phase, and which, on atrophy of the papilla, assumes the whole role in the extrusion process.

NAILS

In the case of the nails the entire substance of the nail plate is made up of flattened, horny epithelial cells very firmly united. The nail bed where the structure is formed is made up of epithelial cells which are continuous with the surface epidermis. Here again,

as with the hair the process of building structure is united by a transitory cell stage with the process of extrusion in the distal epithelium, though through its proximity to the surface and because of the fact that the nail is composed altogether of flat transparent cells homologous to those of the stratum lucidum of the skin, the whole process is almost identical with that of the procession in the epidermis proper. However, the nail is definitely formed before it is extruded, although possibly added to somewhat beyond that point on its under surface according to some authors. The nail moves forward through new formation of nail substance in the region of the matrix. This growth constitutes the positive force for extrusion. The nail-plate thus moves forward over the nail-bed which is composed of cells of the malphigian layer of the skin. The shedding of the cells of this layer is toward the nail plate in the process of their cornification. This factor is undoubtedly a part of the mechanism of extrusion of the nail.

THE TOOTH

The epithelial procession in the case of the tooth is essentially the same as is the case with the hair and nails, *i.e.*, first ingrowth of epithelial cells, then formation of structure, and lastly extrusion. In the formative phase of the tooth the activities of the connective tissues and epithelium are more extensive and complicated than is the case with the hair and nails. The variety of components of the structure, and the extent of the building process thus differentiate the tooth rather markedly from the other appendages. In the process of building, the tooth germ or primordium develops outward toward the surface; the connective tissues and epithelium again collaborate in the building of the structure. This development is featured to a great extent by connective tissue cell activity, *e.g.*, formation of dentine and cementum, as compared to hair and nail development in which the epithelial cells take the dominant part.

Eventually then, in this outward development of the tooth primordium the outward boundary of the structure comes in contact with the oral epithelium, with which the external enamel epithelium joins. At this point the initial eruptive force which is represented in the formative phase, is thereby augmented by a new extrusive process, which is created by the growth factor characteristic of the oral epithelium.

EXTRUSION OF THE TOOTH INTO THE ORAL CAVITY

The extrusion of the tooth into the oral cavity, until all the enamel surface is bathed by the saliva, is known as eruption of the crown. The crown edge arrives at the occlusal line considerably before this takes place. Sometime between the second and third decade, while the tooth is under biting function, the base of the gingival crevice reaches the enamel line, thus completing the crown eruption. According to the concept of Gottlieb, the extrusion of the tooth into the oral cavity does not terminate at this point, but is continued, and this extended process is to be regarded as part of the normal physiology of the tooth. Other workers again, including Becks, deny the operation of this crown-and-root extrusion. In our opinion, taking into account certain microscopic findings in relation to the epithelial cell rests, and pertinent clinical observations of a special nature, there appears to be considerable support for the conclusion that a process of continuous extrusion exists.

It is highly probable that the force concerned in the extrusion of the crown to the occlusal line, following penetration of the oral epithelium, is a continuation of the initial eruptive propulsion incident to the growth and formation of the tooth. And further, this same force would operate in the extrusion of the crown until its full eruption has occurred. It is our contention that the force primarily concerned in any added extrusion which would imply a root extrusion is occasioned largely if not solely by the operation of the mass extrusive force of the growing oral epithelium. It would appear that the beginning of this phase coincides with the completed formation and calcification of the root apex, and it is suggested that at the same time when the mass-extrusion force of the oral epithelium becomes operative the initial eruptive propulsive force subsides.

This additional extrusion is exclusive, of course, of all pathological changes in the periodontal membrane that tend to expel the root from the alveolus, but does not exclude the influence of pathological changes in the gingival tissues on the mass-extrusion force of the attached epithelium. Indeed the bearing of inflammatory gingival changes may tend to accelerate the operation of this force. That is to say, in inflammation with a larger epithelial attachment and further proliferation in the corium, the mass of epithelium is thereby increased. With this increase of epithelial growth, it seems

reasonable that the mass-extrusive force would be increased, and this opinion seems to find some confirmation in certain clinical observations.

When the erupting crown makes contact with overlying oral mucosa, and before dissolution of the mucosa takes place, keratinization of the external enamel epithelium immediately overlying the tip of the enamel is to be observed. This is the first evidence of cuticle formation on the crown. The inner cells of the external enamel epithelium are first attached to the enamel by a bonding substance, a product of the cells, and later through increase of keratohyalin, and formation of keratin in these cells, the homogeneous cuticle is formed.

As the tooth emerges through the oral epithelium a cleavage takes place, with the ultimate result that a small crevice is formed. This crevice is lined on the soft tissue side by epithelium and on the tooth side by cuticle. A controversy exists as to the origin of the epithelium lining the crevice. According to the viewpoint of Gottlieb and Orban, a split takes place between the cuticle and the external enamel epithelium thus making this tissue the lining of the crevice. According to Becks, the bottom of the crevice will always be found at the point where the oral epithelium joins the degenerating enamel epithelium, thus producing in every case, a crevice lined with oral epithelium. According to both viewpoints, long before the base of the crevice has reached the enamel line an epithelial attachment is to be found on the cementum as directly continuous with the epithelium lining the crevice. This finding is confirmed in our microscopic preparations. With further deepening of the crevice the enamel line is reached a stage in the eruptive process pointed out previously as full crown eruption. It is at this point that we suggest that the beginning of the operation of the mass-extrusion force of the oral epithelium occurs with its consequent bearing on the further extrusion of the tooth. Also, this positive force may have a bearing on the direction and rate of tooth movement. Further, this force normally exerting a continuous tug on the tooth root must be a factor in the maintenance of the connective tissue structures intimately associated with it. In any further investigations this process obviously should not be overlooked.

In our microscopic observations many examples are to be found which exhibit no definite line of cleavage between the cuticle and

the epithelium. Frequently the soft tissue side of the cuticle shows adherent epithelial cells. The weakest point appears to lie between the stiffened cells bound to the cuticle (or tooth surface when the cuticle is lacking) and the more plastic body of epithelium which is further inward from the surface (Fig. 4). As inferred above, a definite formation of cuticle is not always present but in all cases the process of gradual hyalinization toward the tooth surface, as seen microscopically, is assumed to denote the presence of the keratinization process even when there is no well developed cornified structure discernable (Fig. 5).

On the outward movement of the tooth, the attachment epithelium is continuously being detached at its crest. But it is also being continuously attached at the lowest point of contact with the tooth surface; so that naturally the epithelial body maintains a rather constant adaptation with the tooth. This intimate union with the tooth surface is continuously being made at the base of the attachment and is effected by the same process as that by which the epithelial cells first became cemented to the enamel of the erupting tooth. Thus newly forming cells above the germinative layer produce newly formed cement substance at the base of the epithelial investment (Fig. 6); this substance is of a fluid, mucilaginous nature when first produced. The fluid nature of this secretion and the rough and somewhat porous nature of the cementum surface (Fig. 7) would appear to offer ideal conditions for insuring an intimate initial contact, and which, upon gradual hardening would result in the ultimate rigid union of epithelial cells and tooth surface (Fig. 8).

MASS-EXTRUSION FORCE

We have pointed out previously that the epithelial cell mass moves outward continuously by the addition of new cells to the inner layers. This cell proliferation is continuous so that the mass-extrusion force must also be continuous, although the rate of the proliferative processes may vary considerably in the same and in different individuals. The hypothesis frequently referred to in the earlier pages of this paper is herein more specifically stated. We present the theory that the mechanical force exerted by this epithelial cell-mass movement, by virtue of the epithelial investment at the neck of the tooth or deeper portions, brings into action a positive extrusive tendency of the tooth itself. As the cells of an

epithelial papilla tend to differentiate and become hyalinized and keratinized inward and upward in the papilla toward the surface (an evidence of mass-extrusion) so does the epithelial attachment, viewed from the standpoint of a split papilla, adapted and attached to the tooth, undergo the same processes (Figs. 1, 9). The cuticle is representative of the central hyalinization of the papilla and must obviously be subjected, through its attached cells, to the same outward progression.

It is realized that this extrusive force may be reduced to a mere potential tendency by pressure directed against it, *e.g.*, biting pressures which would nearly nullify the extrusive force as it is in operation around the tooth. Indeed, the force working harmoniously should just compensate for the abrasion of the wearing surfaces of the teeth. It is highly possible that in certain individual teeth the occlusal and articular forces are of such magnitude as to completely inhibit the process, and it would seem reasonable that such disturbance of a natural physiological process would not be free from injurious consequences. The reverse of this condition, as pointed out by Halliburton⁵, is commonly noted, where, in the absence of occlusal function a gradual process of extrusion is apparent.

It is conceivable that under certain adverse conditions, from different sources, physico-chemical alterations in the environment of the epithelial attachment may occur which would favour further deepening of the crevice. A discussion of the bearing of disruption of the epithelial growth-extrusion mechanism on gingival conditions is quite outside the scope of this paper. We are of the opinion however, that in the search for causal factors in abnormal gingival conditions the physiologic and physico-chemical processes which especially appertain to stratified squamous epithelium have not received due consideration and study.

REFERENCES

- ¹Cowdry: The Skin; Cowdry's Special Cytology, Vol. 1, Paul B. Hoeber Inc., 1932.
- ²Smith: Growth; Oliver and Boyd, 1932.
- ³Huxley: Lessons in Elementary Physiology; MacMillan & Co., 1920.
- ⁴Jordan: Text-book of Histology; Appleton-Century, 1934.
- ⁵Halliburton: Hand-book of Physiology; 21st ed., P. Blakiston's Son & Co., 1908.

We gratefully acknowledge our indebtedness to Dr. Harold K. Box, Dr. Arthur C. Hendrick, and Dr. A. W. Ham for helpful suggestions and criticism.

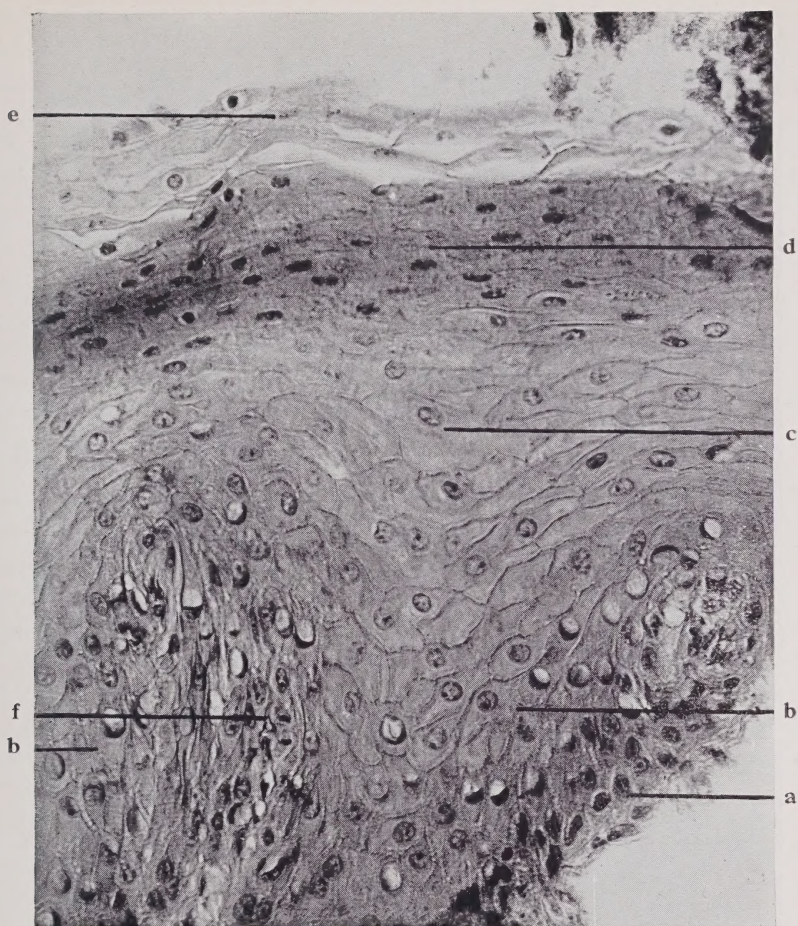


Fig. 1.—Section of epithelium (human) from the marginal gingiva showing fairly normal and progressive nature of the changes in the epithelial cells from the innermost basal cells, to the desquamating cells on the surface.

a, basal layer; b, prickle or polyhedral cells; c, hardening keratohyalin zone with loss of intercellular bridges or prickles; d, zone of flattened homogeneous cells filled with keratin; e, scaly desquamating cells at surface of gum; f, epithelial cell in late stage of division showing polarity perpendicular to the surface.

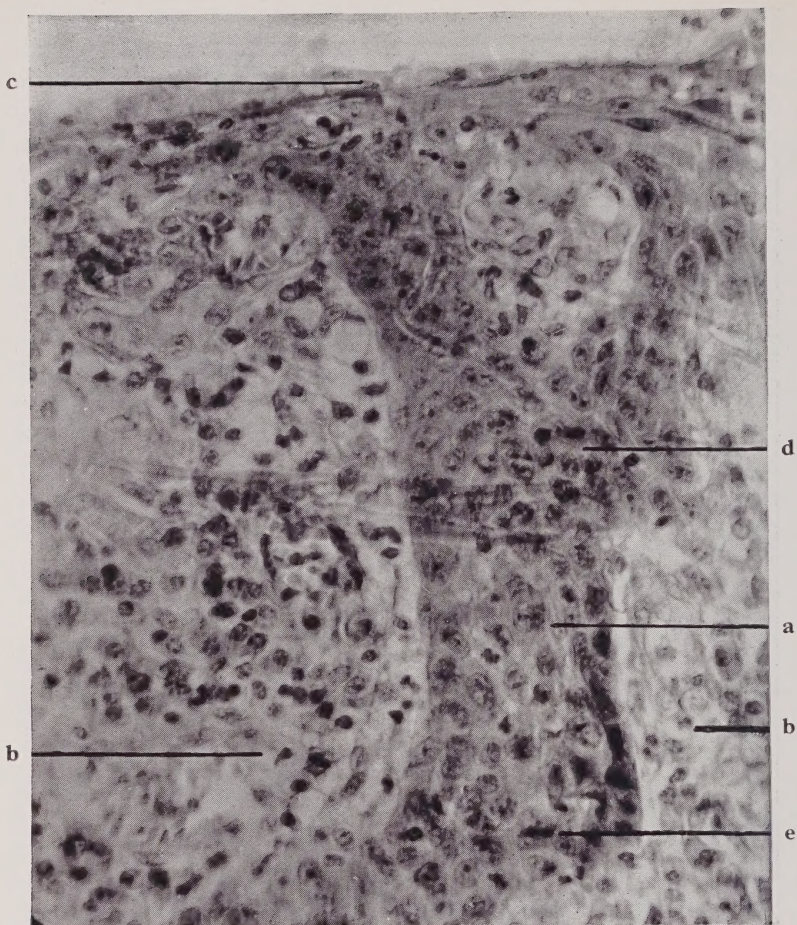


Fig. 2.—Epithelium lining the gingival pocket (human), showing degeneration of epithelial cells at the surface, with rapid growth and replacement [from below.

a, epithelium; b, connective tissue; c, surface; d, two epithelial cells in late stage of division; e, epithelial cell in earlier stage of division. Note that polarity (as indicated by arrangement of chromosomes) is perpendicular to the surface, denoting the procession outward.

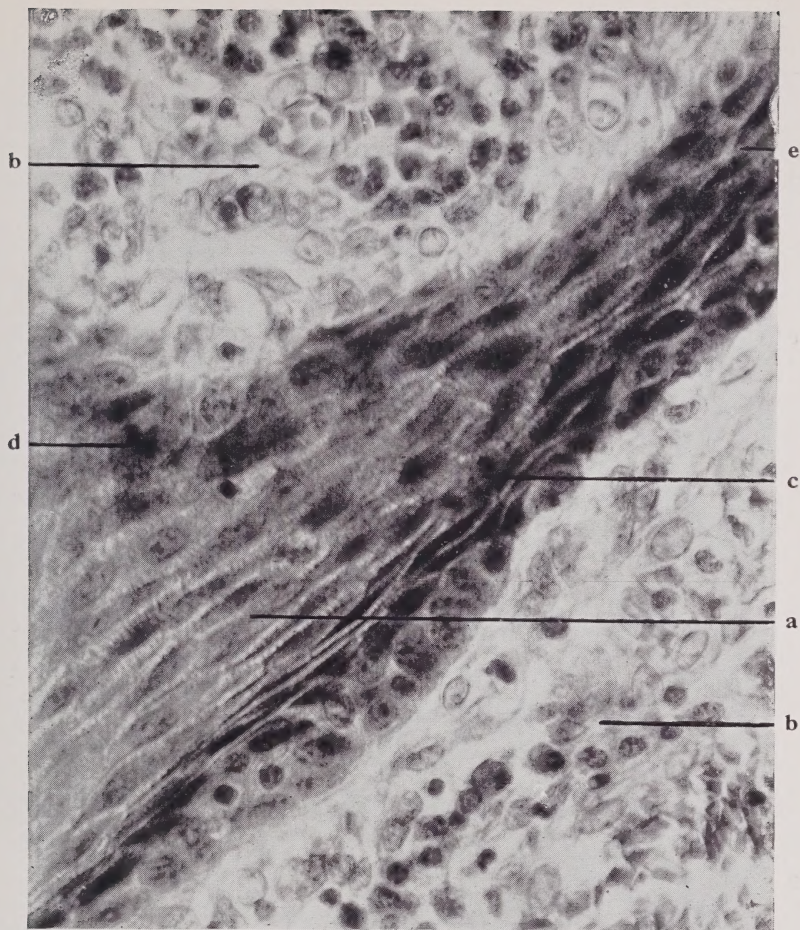


Fig. 3.—Higher power illustration of epithelial cells (human gingival tissue) in division, denoting progress of growth toward the surface.

a, epithelial papilla; b, connective tissue; c, late stage of division; d, earlier stage of division; e, toward the surface of the gum.

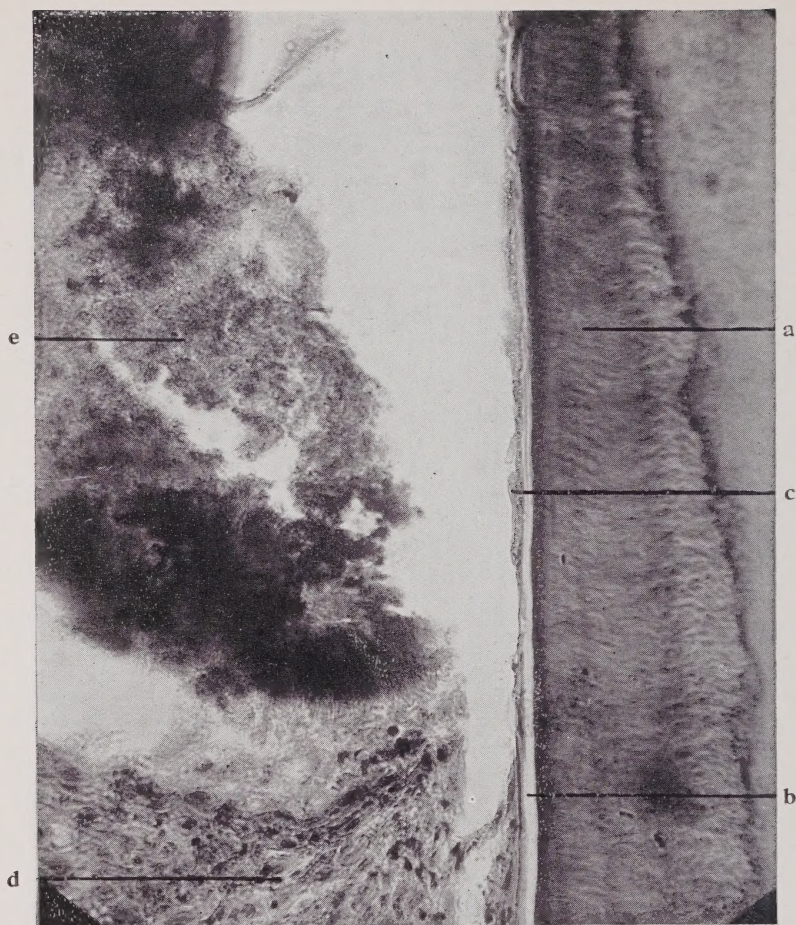


Fig. 4.—Specimen from human material showing base of the pocket with cuticle attached to tooth surface above. Note rigid cell remnants still cemented tightly in the cuticle above the point of splitting of epithelium away from the tooth surface.

a, tooth cementum; b, well formed cuticle; c, epithelial cells rigid with keratin cemented or bound in the cuticle; d, epithelial tissue attached to the tooth; e, calculus.

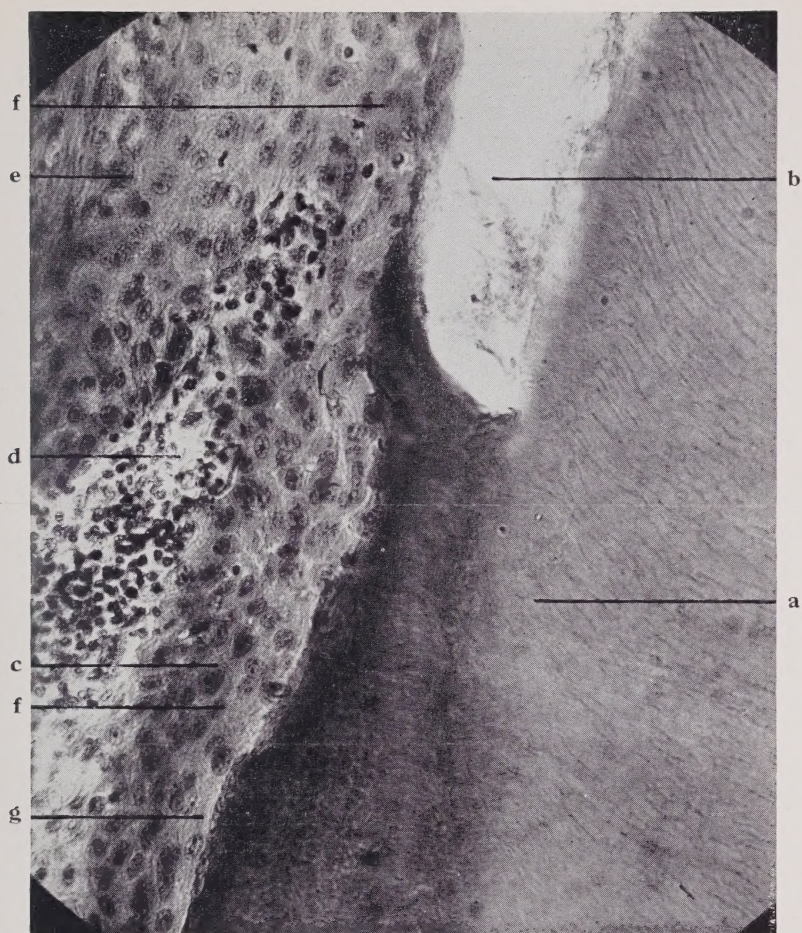


Fig. 5.—Section from human material showing the absence of a well defined cuticle on the tooth surface. Prickle cells are seen to be displaced by keratohyalin-filled cells lacking intercellular processes as the surface of the cementum is approached.

a, tooth; b, enamel space after decalcification; c, epithelium attached to tooth surface; d, connective tissue; e, prickle, or polyhedral cells; f, homogeneous, keratin-filled cells; g, hyaline zone (but no definite cuticle) adjacent to, and bound in the rough cementum surface.

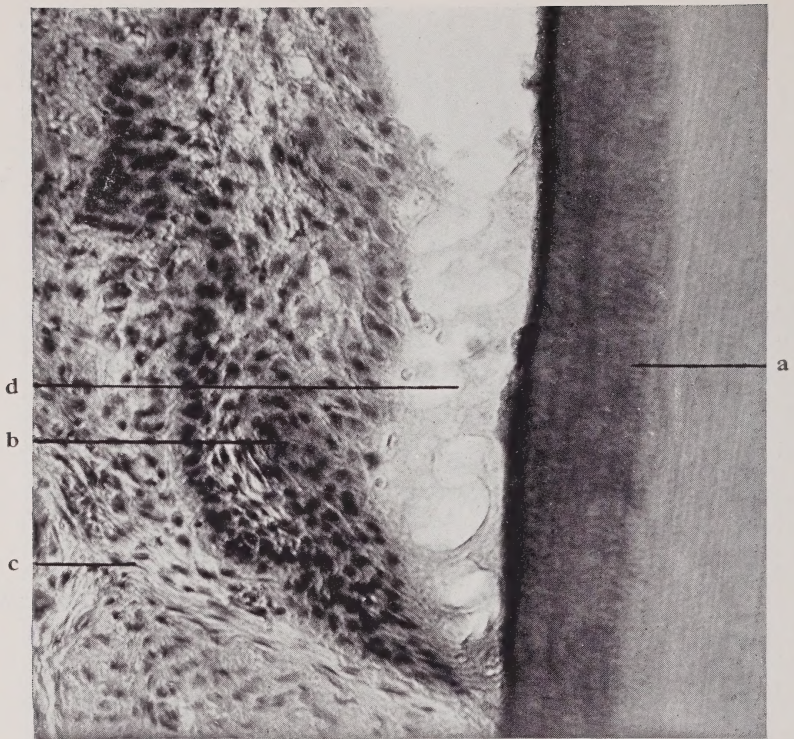


Fig. 6.—The mucilaginous cementing substance is here seen to provide the initial bond between the epithelium at the basal extremity and the tooth surface. (As in Figs. 4, 7, and 8, which reveal splitting of the epithelium down its most vulnerable point, the value of this illustration is enhanced by shrinkage artefact.)

a, tooth; b, epithelium; c, connective tissue; d, fluid nature of mucilaginous cell secretion of vital young cells at the base of epithelial attachment.

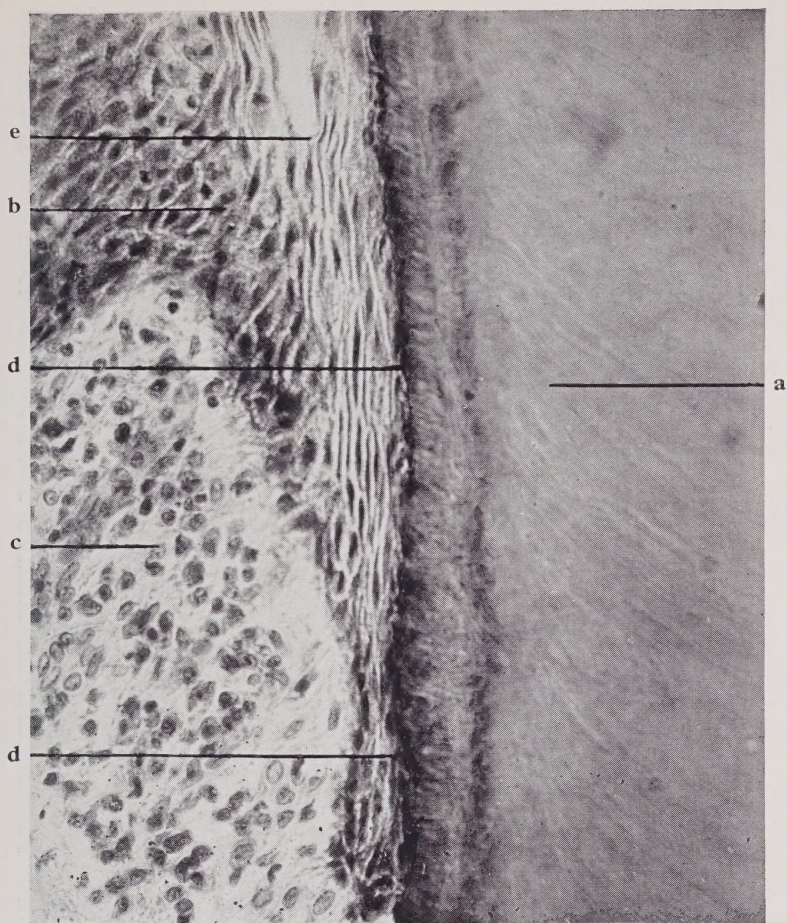


Fig. 7.—Epithelial attachment (human) showing rough nature of cementum surface; with epithelial cells in intimate contiguity with surface. The illustration shows the base of the epithelial attachment, and also the cleft (from above) through the weakest point in the epithelial structure, *i.e.*, between the rigid keratin filled cells adjoining the tooth, and the more plastic, vital cells of the deeper layers of the tissue.

a, tooth; b, epithelium; c, connective tissue; d, rough cementum surface; e, natural cleavage zone of the epithelium under undue stress.

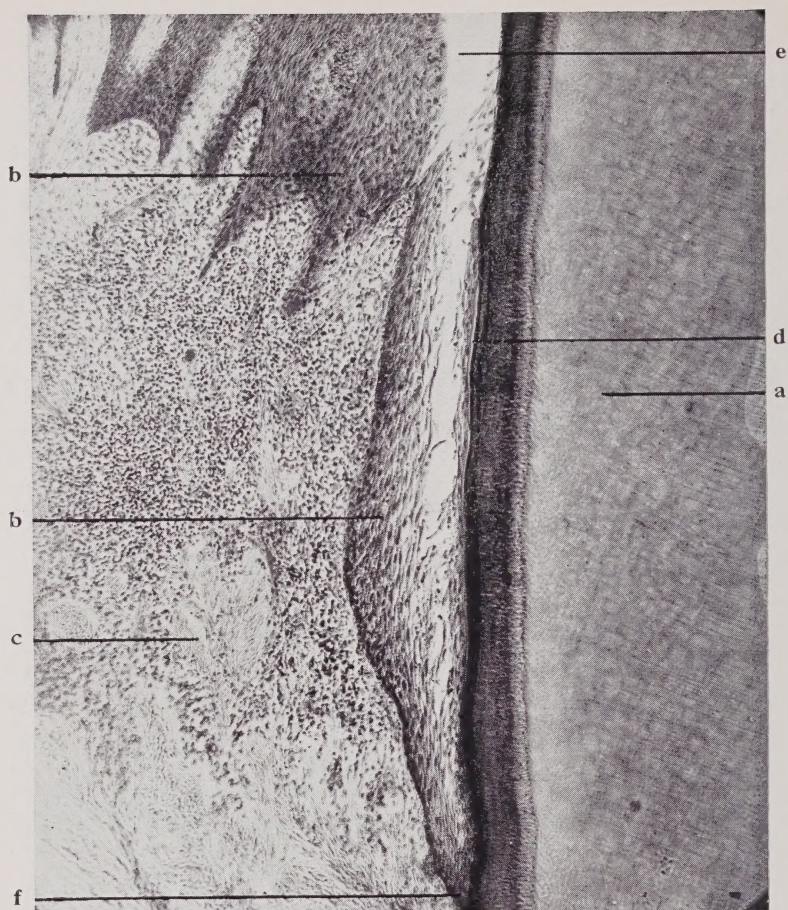


Fig. 8.—The epithelium which is bound to the tooth surface showing the base of the pocket and fairly well marked cuticle formation. The splitting through the body of the epithelium is, of course, brought about by shrinkage in preparation of the material for sectioning. It is to be noted that this division takes place (under abnormal stress) not along the cuticle margin, nor yet along the surface of the tooth, but in the body of the epithelial structure.

a, tooth; b, epithelium; c, connective tissue; d, cuticle; e, base of pocket; f base of epithelial attachment.

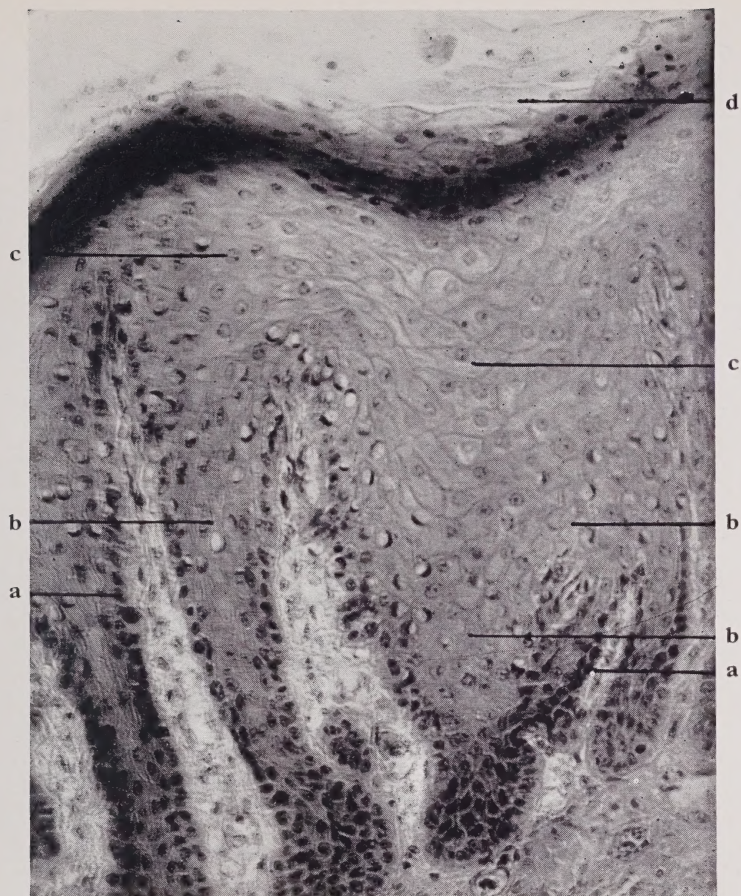


Fig. 9.—Epithelial papillae from region of the crest of the human gum. Note the progressive hyalinization and gradual keratinization toward centre and upward toward the surface in the larger cell mass.

a, basal cells; b, prickle cell layer; c, homogeneous keratohyalin filled cells homologous to the bonding substance attaching the epithelium to the tooth; d, desquamating cells at the surface.

Glass as a Denture Base

BY

FRANK M. LOTT, D.D.S., B.Sc. (Dent.)

BULLETIN NUMBER TWENTY-THREE

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1936

Glass as a Denture Base

BY

FRANK M. LOTT, D.D.S., B.Sc. (Dent.)

BULLETIN NUMBER TWENTY-THREE

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

July, 1936

PRINTED IN CANADA

CONTENTS

CHAPTER I

	PAGE
REQUIREMENTS FOR AN IDEAL DENTURE BASE.....	9

CHAPTER II

THE DEVELOPMENT OF A SUITABLE GLASS.....	13
--	----

CHAPTER III

THE DEVELOPMENT OF A SATISFACTORY TECHNIQUE.....	18
--	----

CHAPTER IV

ELABORATION OF THE FINAL TECHNIQUE.....	41
---	----

CHAPTER V

SOME MISCELLANEOUS PROPERTIES OF GLASS.....	49
---	----

CHAPTER VI

DISCUSSION OF THE PROPERTIES OF GLASS IN COMPARISON WITH THOSE OF THE IDEAL DENTURE BASE.....	52
SUMMARY.....	62
BIBLIOGRAPHY.....	63

ILLUSTRATIONS

FIG.	PAGE
1. Tench type flask used in making the first moulds.....	19
2. Tench type flask with pieces for insertion of handles.....	20
3. Tench type flask with handles inserted in extension pieces.....	20
4. Flask with lugs cut to permit closing it from the anterior.....	21
5. Tench type flask with broad hinge across the back.....	21
6. Tench flask with cam at the anterior—open.....	22
7. Tench flask with cam at the anterior—closed.....	23
8. Tench type flask showing the square extension of cam on which the handle fitted.....	24
9. Early type of horizontal furnace.....	25
10. Taggart-type casting machine with attachment for holding flask to the casting head.....	27
11. Flask with key-way to fit Taggart-type machine.....	28
12. Large size Metallurgy Department gas furnace.....	29
13. Furnace mounted on base of bench press.....	32
14. Pit type furnace with stationary upper structure to guide spindle.....	33
15. Pit type furnace with removable upper structure.....	34
16. Pit type furnace with upper structure removed altogether.....	35
17. Pit type furnace with yoke and lever arrangement.....	36
18. Tench type flask fitted with extra long lugs.....	37
19. Silal flask separated to show the three sections.....	38
20. Silal flask assembled.....	39
21. Various sections of the Nicrosilal flask.....	39
22. Nicrosilal flask shown assembled.....	40
23. Side view of the waxed-up denture imbedded in the bottom section of the flask.....	42
24. Posterior view of the waxed-up denture imbedded in the bottom section of the flask.....	42
25. The flask showing the mould after separation.....	43
26. The female part of the mould packed with glass cane in short lengths....	44
27. The flask assembled, male part resting lightly in position on the packed female part.....	45
28. A slow speed apparatus made up for cutting and grinding glass.....	47
29. Gnathodynamometer in position in the mouth.....	55
30. Table of results of gnathodynamometer tests.....	56
31. Questionnaire accompanying each experimental denture inserted.....	61

ACKNOWLEDGMENT

The pursuit of research subjects, such as the present one, is always accompanied in the mind of the author by a deep sense of gratification because of the contacts made with men it is a privilege to know or to know better as a result of having met them for a time at least on a common ground. It is, therefore, a pleasure, indeed, for the author to acknowledge his indebtedness to all those whose learning and patience made the present work possible.

F. M. LOTT.

Toronto, April 21st, 1936.

INTRODUCTION

One of the most widely required and yet one of the most difficult dental services is the construction of an accurate and efficient artificial denture.

From the diagnosis of the pre-denture mouth to the insertion and maintenance of the denture, the operator requires a very intimate knowledge of many divisions of this great subject.

Each division has its own circle of earnest investigators and it is one of the most reassuring and hopeful signs of advance by the profession that each of these circles is constantly increasing the number of its devotees and the enthusiasm with which they are throwing themselves into the study of the subject.

One of the most interesting of these major subjects is the search for the ideal denture base. Keen as is our appreciation of the achievements of our predecessors, very few of us are satisfied with the present situation. Patients are insistently demanding more natural appearing dentures without, of course, undue sacrifice of other necessary properties and our profession feels it to be our responsibility to attempt, at least, to meet this requirement.

The reasons for the decision to experiment with glass can be given in a very few words.

Here was a material known to have wonderful hardness, tenacity and general stability that in the past had been processed into many forms by various methods.

It was capable of an extremely wide color variation and suitable colour, once established, would be of a permanence so far quite unknown in denture bases.

In addition, glasses were known that would seal to porcelain and various metals. Thus, it was reasonable to hope that one could be developed to seal to our porcelain teeth and, later, to metals for partial denture work.

The prospect was very inviting. There promised to be many difficulties but if the result could be attained it would far outweigh in importance the time requirement for the accomplishment of it.

It is to this end that the author dedicates the present work in the hope that it will be of some value to profession and patient alike.

F. M. LOTT.

Toronto, April 21st, 1936.

CHAPTER I

REQUIREMENTS OF AN IDEAL DENTURE BASE

The search for this perfect denture base may logically be commenced by an elaboration of the requirements of the ideal condition as a specification of the standard of excellence to be striven for.

The situation is complicated by the fact that no mathematical standards have been established for denture base materials as with other dental materials. For instance, an expanding investment must meet the requirements of the Research Commission of the American Dental Association. The graph of its behaviour may then be printed on the company advertisements together with a certificate of satisfactory performance. In the same way, a gold alloy must fill certain specifications as to tensile strength, elongation, melting point, etc. But, in the case of denture materials, no such data have been determined with the result that a comparison is usually made with vulcanite as a yard-stick. This method is decidedly not scientific but it has the advantage of being readily understood by the dental reader.

Color is one of the most important of the requirements: indeed, it is felt by many operators that the general dissatisfaction of profession and patients with regard to the very unnatural appearance of vulcanite was the first great incentive towards improvement in denture bases. That it still holds this place seems to be well proven by the fact that it is invariably the first question asked when the subject of a new denture base is under discussion.

Everyone will agree that the color of the base should duplicate that of the gum tissue being replaced.

In addition to being correct, the colour should also be permanent. This will be more fully explained under the heading of stability.

Translucence is a property that can well be discussed in close association with colour.

Vulcanite has always been criticized because it has a dead, opaque appearance and the author listed this objectionable feature as one to be eliminated in the new material, if at all possible. Much to the surprise of everyone, however, when a slight translucence

was finally secured in the glass base, the necks of the teeth showed through it and the opacity had to be re-established.

The dentist has always referred to this requirement of depth, as he fondly terms it, but a few translucent glasses proved conclusively that an extremely small amount only can be tolerated without disclosing the necks of the teeth. On the other hand, it seems to be only a matter of careful contouring of the labial and buccal flanges and a high polish that are required.

The *Strength* should be adequate for all dental requirements.

The *Stability* may well be considered next in order.

From a physical standpoint, the base of the finished denture should be free from internal strain to prevent distortion and other physical changes. This statement refers particularly to a denture in ordinary use. On the other hand, there is no reason why distortion should occur in a denture left accidentally in a dry, warm place for some time. In fact, it should not be too much to expect that one should be able to sterilize a denture in boiling water without fear of distorting it.

Heat, although necessary for processing it, should not affect the colour within reasonable limits. Thus, the colour should not be so critical or fleeting that a few degrees above or below the required processing temperature will seriously affect it. Once established, it should not be altered by such an operation as polishing where a dry buff may run on the surface for a short interval or by re-processing for repair or alteration purposes.

From the chemical standpoint, there should be no deterioration of the unused material. This is usually described as shelf-life. It becomes a serious problem for the dealer who must buy a quantity to get a price or who must import it into far distant Australia, for instance, and thereby subject it to a long journey under varying atmospheric conditions.

Light should not change the color in any way. Thus, a dealer should not be required to store it in a dark place. On the other hand, he should be able to place new material or a denture on display without fear of having it fade.

No content in the oral secretions of the patient and no food or drug that is taken into the mouth should affect it. In the same way, it should not be acted upon by any drug, such as a disinfecting solution, to which it may be exposed when out of the mouth.

Stability is thus seen to be a very important requirement because it involves so many other properties.

The *Density* should be uniform and such as to render the base absolutely impervious to oral fluids, food debris and bacteria. The greater the density, the more hygienic will be the denture because nothing will secure a foothold in it. This same point has a bearing on the colour situation because there will be no film to alter it.

Wetting Ability is a property that is closely related to density. The latter term was associated altogether with impenetrability of the base material. But a denture may also become foul in the mouth if there is not a perfect seal between the denture base and the porcelain teeth. This property of a material by which it makes a strong, close and permanent union with the teeth is usually known as its wetting ability. At the time of pressing it demands a certain degree of fluidity to permit it to make this intimate contact with the teeth. Afterwards, the properties of hardness and stability must be such as to permit it to retain this relation.

Welding Ability is an additional property that can well be discussed along with density. Welding is defined by Hodgen¹: "The process of joining two clean surfaces of a substance, such as a metal, together by pressure. Thus, iron will cohere at white heat, gold will cohere at room temperature in proportion to the state of purity."

The possession of this property insures the density of a denture base in those cases where repairs or alterations must be made.

The *Hardness* may well be considered along with density. It should be of such a high order that the surface of the material will take a high and lasting polish. This property coupled with proper density further precludes a foothold to food debris, stain, etc.

Elasticity is a very necessary property. It can be defined as the ability of a material to recover its shape after being acted upon by a deforming force. Many operators feel that fracture is obviated by the fact that a material will bend rather than break. However, if the strength of a material is such that the masticatory forces will not bend a dental base, the author does not feel that anything important has been sacrificed.

The elastic limit of the material should be well above the value of the masticatory forces deforming it in order that permanent

¹Joseph D. Hodgen, Practical Dental Metallurgy, page 34.

deformation or fracture will not occur. In addition, the return of the material to normal should be as rapid as possible after long-repeated deformations. In other words, deterioration due to continued repetition, or fatigue, should be as low a value as possible.

Volumetric Change is an important property.

The coefficient of expansion should be as low as possible. It is generally conceded that rubber changes approximately three and one half per cent during vulcanization. Any value below this is naturally more satisfactory but it really should be very much less because vulcanite has long been criticized on the point.

The *Weight* is a factor worthy of discussion. It is generally felt that the weight should be just as little as possible. This is more generally true of an upper denture than a lower. If the variation is such as to keep the weight of a denture within a very few penny-weights of a corresponding vulcanite denture, it is satisfactory. In other words, patient and dentist are accustomed to vulcanite and use it as a standard.

The *Thermal Conductivity* of a base should be of high order to maintain tissue tone beneath it. This has always been quoted as an advantage of metallic over non-metallic bases.

No *Odour* should be emitted by the base. It is just a question whether this property should not be associated with stability. It is the opinion of the author that any material giving off an odour is deteriorating.

Similarly, no *Taste* should be associated with it.

The *Cost* of the material should be as low as possible. This also applies to the accompanying supplies and equipment.

Practical Working Properties as viewed from a dental standpoint are also very necessary. Thus, the technique for its use should not present too great a deviation from present procedures. Individual moulds must be used, preferably of gypsum derivatives for various reasons and the technique of manufacture, repairs and alterations should be simple, short and not too critical.

CHAPTER II

THE DEVELOPMENT OF A SUITABLE GLASS

With the knowledge that many properties of glass make it a very desirable denture, the story becomes essentially one of technique with accompanying supplies and equipment.

Two sets of conditions were immediately recognized: first, those regarding the glass and, second, the dental technique to be developed if it were to succeed in the new field.

For months after experiments began, very little attention was paid to the glass problem because work was proceeding on improvements of flasks and mould materials. At this time, the working properties of glass were practically unknown to the author and adaptation of dental technique to any kind of glass was a slow, tedious process.

During this period, glass tubing was used, a type of glass that could be easily softened in an open flame.

In the summer of 1932, the problem was accepted for co-operation by the Research Department of one of the greatest glass companies on the continent and since that time, well over fifty different glasses have been supplied with characteristics as demanded by the constantly changing technique. It is plainly stated here that the author has attempted the compounding of glasses in a small number of cases only. A first class knowledge of either the physics or chemistry of glass is the work of a life-time itself. In addition, there is that great wealth of practical knowledge that can only be acquired by generations of association with it. For these reasons, it was felt by the author that the time possible to devote to this division of the problem even over a period of years would be hopelessly inadequate for the attainment of that standard of excellence that such a company already possessed. Therefore, the production of satisfactory melts was left to the company with its great resources of knowledge, equipment and supplies. The author feels quite justified in limiting his activities in the glass field to determining his requirements and testing the subsequent products from the dental standpoint.

The first thought was to secure a glass with a minimum softening

point in order to conserve the dental heating unit, flask and mould material. Accordingly, the company provided samples ranging from 1013-1292 degrees, Fahrenheit. It might be well to state here that the softening point is more or less of an empirical figure defined by the company as that temperature at which a rod of glass 23 centimetres in length and .55-.65 millimetres in diameter will elongate of its own weight in the furnace at the rate of 1 millimetre per minute.

Experiments rapidly proved that this range of softening temperatures was satisfactory as regards processing equipment and supplies but as soon as porcelain teeth were incorporated in the mould, the multiplicity of cracks in both teeth and glass pointed to one or both of two conditions: first, there was possibly too great a difference in the rates of expansion of the glass and the porcelain of the teeth in the mould and, second, there was a wide difference in the temperatures of the mould and the glass at the time of processing. It was illogical to consider any alteration in the characteristics of the porcelain in the artificial teeth, therefore, it seemed at once advisable to attempt the development of a glass of the same coefficient of expansion as the porcelain. At the same time, it was felt that the processing technique should be changed to one in which mould and glass would be at the same temperature during the entire processing period.

As a beginning, a new series of glasses was selected with a range of coefficients from 36 to 51×10^{-7} per degree, Centigrade, because our dental porcelain was felt to be in the region of from 40 to 50×10^{-7} . Designation of a coefficient of expansion as 36×10^{-7} per degree, Centigrade, simply means that a block of the material will expand $36/10,000,000$ ths. of its bulk per degree, Centigrade, rise in temperature. In future coefficient references, the first number only will be used.

It was felt that, with this new supply of glass, work could proceed on the technique with, perhaps, a certain amount of hope regarding the balance of the coefficients and that, in the meantime, accurate information would become available on the coefficient of the porcelain.

This is exactly what happened. The technique continued to improve slowly but cracking continued to a distressing degree.

Some time later, this porcelain coefficient was established at 88 and a stock glass, Code No. 756, Coefficient 79, became available.

Cracks continued, however, through months of experimentation while information accumulated regarding the technique. Before attention was again turned to the glass, the solution unexpectedly appeared in this way. For a temporary change in technique to a settling method as distinguished from the pressing method then in use, a glass, Code No. G 632-BE, was suggested by the company for the first experiments because it would flow more easily than the No. 756. The coefficient was simply disregarded. Later, the settling method was abandoned for reasons given elsewhere but it was noted with surprise that there were no cracks in the cases processed by this method. The coefficient of this glass was known to be 75, a fact that was very confusing to the Research Department until a re-check on the porcelain teeth established a coefficient of 79 for porcelain.

This glass has been in continuous use up to the present time for, although the color problem has been investigated in the meantime and many red glasses have been tested, all these coloured specimens have been modifications of this same No. G 632-BE.

The coloration problem began to claim attention only about eighteen months ago. In the first place, it was obviously illogical to color glass correctly before it was known whether a technique could be developed for the use of it. Also, it was known that the addition of a coloring agent would affect the characteristics of any glass so treated and its premature introduction would only create an additional unknown factor.

About the time mentioned above, however, it was reasonably certain that an efficient technique was possible and a glass of satisfactory characteristics, No. G 632-BE already described, had been in use for some time. The attempt at the solution of the color problem, therefore, appeared to be the next reasonable move.

Pink glass, although not common, has been and is being produced by two procedures. In one method, a central layer of red glass has a layer of white placed on each side of it and the object is then blown with the result that the red effect is modified to a pink by the thickness of the white layers. It was felt that such a method could not be made use of in dentistry because of the many technical difficulties including especially the uncertainty of the final shade. In addition, even if a denture could be produced with the correct coloration, any grinding during or subsequent to trimming or polishing would alter the shade to a brighter red. By

a second method, the pink coloration is simply stained on. This gave promise of being a perfectly feasible dental technique but with the disadvantage that it involved extra steps and was especially troublesome in repair work. For such reasons, it was felt that the ultimate glass should be inherently of the proper shade of red.

Red glass can be produced by the addition of selenium or gold in certain forms and amounts. At the very outset, however, selenium was given up because it cannot be diluted without the formation of streaks. Since gum tissue is a very mild red, or pink to use the common term, and extreme dilution would be necessary, gold was chosen as the agent because of its greater stability.

At least a dozen different samples were tested over a period of six months. The color in all of the glass was developed as a "warmed-in" process. Each sample, as delivered, was of an opaque white to all appearances exactly similar to the No. G 632-BE of which it was a modification. When it was fired, however, it evolved a red coloration and, happily, it was proven that when once developed, it would not change till the glass was re-melted.

All of the above samples failed, however, because of the blue that appeared in them as streaks, blotches or a homogeneous effect over the entire surface of the samples. In addition, the coefficient was affected with the result that cracks ruined the dentures constructed. And, finally, an increased translucence had been obtained that allowed the necks of the teeth to show through and the company had to be requested to reduce the effect.

Altogether, conditions were temporarily unsatisfactory and the interval until their rectification was chosen to gain some information on the feasibility of staining the dentures to the correct shade.

Works such as those of Whall¹ and Le Couteur² provided a superficial knowledge of the technique: and two companies³⁻⁴, were consulted regarding a selection of low fusing pink stains. After some experimentation with fluxes to modify their fusing points and the use of grounding oil, etc., some promising staining was done.

It was certainly possible to stain the No. G 632-BE glass to any required shade but, as has already been explained, the process

¹C. W. Whall, *Stained Glass Work*, pp. 56-82.

²John D. Le Couteur, *English Mediaeval Painted Glass*.

³O. Hommel Co., Inc., 209 Fourth Ave., Pittsburgh, Pa.

⁴B. F. Drakenfeld & Co., Inc., 45 Park Place, New York City.

involved re-firing the denture under more or less accurate control in order that the denture base would not be softened and thereby ruined. Also, the problem of repairs became much more complicated by the presence of the stain.

This work was given up shortly afterward because of the arrival of further samples for testing but the information gained on staining carried a measure of assurance regarding a satisfactory alternative technique.

Well over two dozen samples arrived in the next few months with corrected coefficient, increased opacity and with colouration improved to a point where it became necessary to decide upon exactly what value and chroma were required.

There were two methods available for determining gum colouration. One was to make a spectroscopic analysis of lip and gum tissues for a large number of patients and record the results in Angstrom units. This would have been a most definite method but it was felt by the advisory committee that it would consume time cut of all proportion to its value because at the conclusion of it there would probably have been no single shade satisfactory for all cases and a compromise would still have had to be made. It is the general feeling in dentistry that only one shade of material should be provided; otherwise, both dental dealer and dentist would require a larger and more diversified stock both for new dentures and repairs and then the patient might further complicate the situation by having a change occur in the living tissue because of ill-health, increasing age, etc.

The other method was to make a less accurate but more rapid and practical survey with the Munsell Color Atlas.¹ The scope of this survey was made as comprehensive as possible by charting gum tissues in health and disease, youth and age, male and female.

The final choice was R 4/6.

The company approximated this result very closely with two glasses, No. 658 DQ and No. 658 DS that are certainly satisfactory for the present at least.

¹A. H. Munsell, Book of Color.

CHAPTER III

THE DEVELOPMENT OF A SATISFACTORY TECHNIQUE

It was recognized at the beginning of the work that, when glass was to be the base, a much higher heat would be required to process it than was ordinarily employed in similar dental procedures. Annealing was also known to be an important factor to prevent strain and possible fracture in the finished product. Later, the correct coefficient of expansion became a necessity. Also, the properties of welding and sealing ability came into prominence and many others that will be taken up in due order.

From the dental viewpoint, a technique was required that, generally speaking, did not present too great a departure from present procedure. It was recognized that dental moulds must be individual and that they always contained porcelain teeth, with or without pins. In addition, processing should not be too lengthy for practice conditions or so critical as be troublesome.

All of these above factors are so completely interwoven that none can be described separately. For this reason, the story of the development of the technique will be concisely given as recorded in the diary. In this way, it is felt that the reader will get a much clearer understanding of the conditions that forced the technique, supplies and equipment through the numerous changes to the present time.

The mould commanded attention in the very first of the experiments and has been one of the most important features throughout.

It is common knowledge that all of the pressed glass and a great deal of the blown glass of to-day is processed in steel moulds. Each individual mould costs considerable money but such an overhead expense is disregarded because of the thousands of manufactured articles that each will produce during its useful life.

Dentistry cannot advisedly use steel moulds because of the time, cost and special training involved in the construction of them. Our profession is practically limited to the gypsum derivatives and especially if present procedures are to be followed as closely as possible. An extract from the *Encyclopaedia Britannica*¹ first gave the author some hope of an adaptation along this line: "The glass

¹Encyclopaedia Britannica, Vol. 10, 14th edition, page 399.

can be moulded into any shape if the bulbs are blown into hollow moulds of stone, wood or metal or, in the case of thick bowls, for example, if the glass metal is pressed from within against the walls of such moulds." Incidentally the very important information that such a quotation did not give was that the mould should be almost immediately opened and the glass object removed and annealed.

Early Attempts in flask design. The dental viewpoint of the author caused him to think along the line of vulcanizing technique. With a gypsum mould that had to be accurately assembled, there seemed to be no better method of closing it than by a confining flask with lugs that would align the two halves perfectly.

Accordingly, for months at the beginning of the work, experiments aimed at nothing further than the use of an ordinary Tench type flask and artificial stone as a mould material to press glass in some such mould, as in Fig. 1, with protection rim and waste ditch in duplication of dental conditions. To reduce the number of unknown quantities, no porcelain teeth were incorporated in the mould.

The glass used was ordinary tubing that could be softened in an open flame, placed in the cold mould and clipped off with a pair of shears by an assistant, while the author simply closed the flask with hands protected by heavy leather gloves.

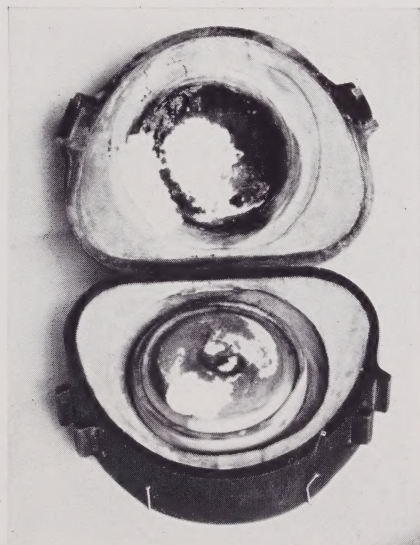


Fig. 1.—Tench type flask used in making of first moulds.

Usually the glass cooled so quickly in the cold mould that the latter could not be closed. No attempts were made to anneal it.

To prevent this condition, a pre-heated flask was decided upon and the design of the flask altered, as in Figs. 2 and 3, to incorporate

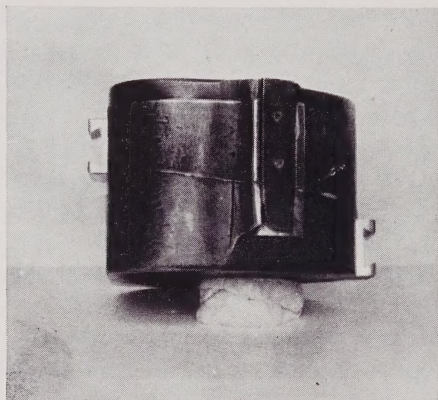


Fig. 2.—Trench type flask with pieces for insertion of handles.

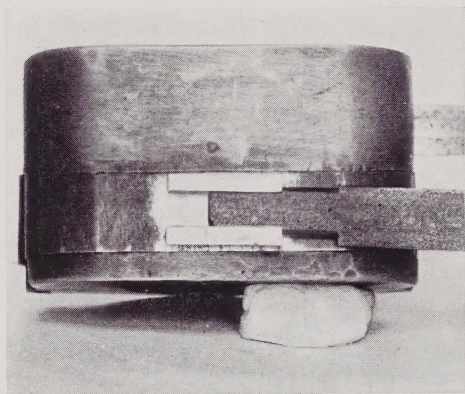


Fig. 3.—Trench type flask with handles inserted in extension pieces.

two handles that would permit manipulation of the flask when its temperature was far too high for the use of leather gloves.

Also, note in Fig. 4 the design of the lugs to permit closure of the flask at the anterior first to eliminate any trouble from high anterior undercuts in the mould.

This design was almost immediately discarded, however, because the handles were not only awkward to use when they were so close together but it was also found that sufficient pressure to close the flask could not be exerted. The idea of closing the flask from the

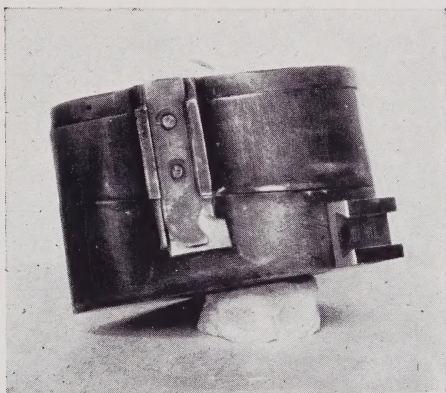


Fig. 4.—Flask with lugs cut to permit closing it from the anterior.

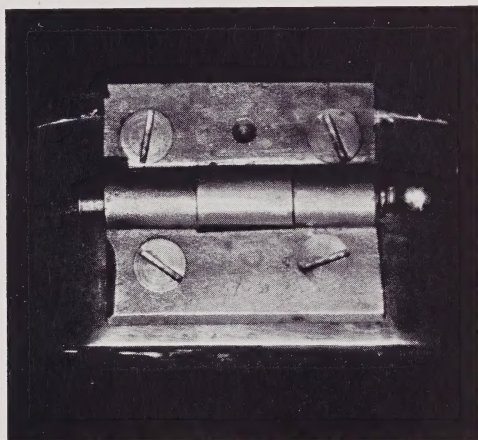


Fig. 5.—Tench type with broad hinge across the back,

anterior was also given up because it was practically impossible to expel the glass posteriorly over a broad, flat palate.

A flask was then fitted with a broad hinge across the back and the lugs were removed, as in Fig. 5.

At the anterior was a cam, shown open and closed, as in Figs. 6 and 7.

On this cam was a square extension that could be engaged by a handle. This is shown in Fig. 8. This handle was to be used to remove the pre-heated flask from the furnace, also, to rotate the cam to close the flask tightly.

Another feature of this flask is worthy of mention. For some time, trouble had been caused by the top falling off the upper part of the flask as it was inverted prior to being filled with glass.

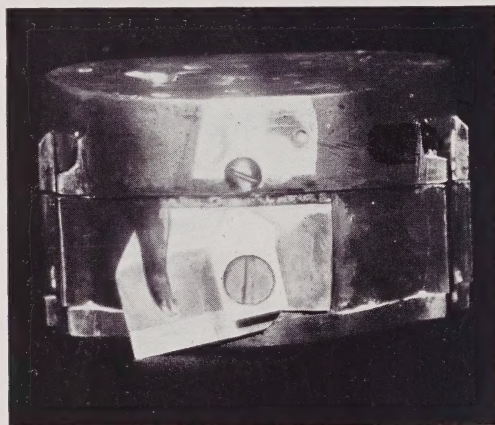


Fig. 6.—Trench flask with cam at the anterior—open.

A button about one inch in diameter, one-quarter inch in thickness and well tapered on its circumference was rivetted to the cover. This undercut button engaged the mould material during flasking and subsequently held the cover in place so efficiently that it has been included in every flask design since.

The development of a technique now began that looked more like a dental procedure because of the inclusion of porcelain teeth in the mould.

A duplicate cast of a case was made in Pyromold Investment No. 1 and the set-up was flaked in the same material.

After separation, a generous waste ditch was cut all round the cast and all exposed mould material was painted with a thin coat of Aquadag solution.

A few pieces of cullet, Code No. G 980-A, were placed in the

mould and the flask was placed in a large Globar furnace at the Ontario Research Foundation.

The technique proposed was simple. Heat was to be increased until the glass was soft enough to be pressed, then the flask was to be closed by the cam.

All went well until pressure was put on the cam. It distorted badly and a long iron rod had to be substituted to exert sufficient pressure on the flask to close it.

The case was allowed to cool in the furnace over night.

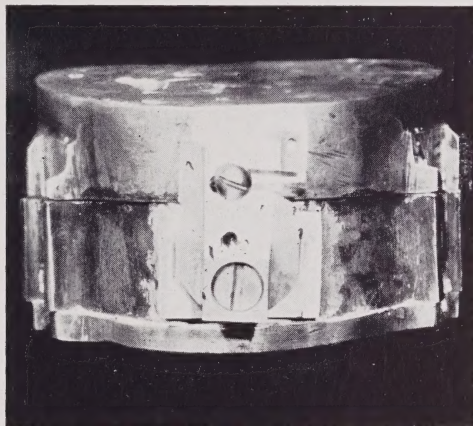


Fig. 7.—Tench flask with cam at the anterior—closed.

As usual with many of these experiments, the results of the first attempts were disappointing. In this particular one, for instance, a few teeth were cracked and the glass badly so. On careful observation, however, it revealed some valuable information.

The protection rim of the cast pinched off the glass nicely and the waste ditch functioned equally well in accommodating the excess. Both of these features have been continued until the present time.

The attachment of the glass to the teeth was a revelation and the adaptation of it to the fine lines of the mould was most encouraging.

The use of Aquadag as a separating medium was well thought of and continued for some time until it was suspected of causing gassing. Finally, it was omitted in one experiment with a surpris-

ingly superior result and it has not been used since. But the idea of a separator persisted. Graphite was incorporated in the mould material for a time, then water glass and sugar solution were used in turn. The best that can be said for any of them is that they probably did no harm. Finally, all were dropped.

It was realized that several unknown quantities existed; the flask scaled badly in the heat, the Pyromold was not sufficiently hard and glass and teeth cracked.

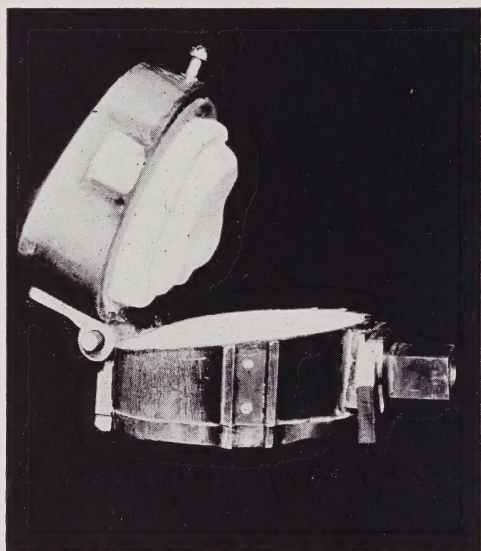


Fig. 8.—Trench type flask showing the square extension of cam on which the handle fitted.

It was felt that this cracking was altogether likely to be due to a disparity in coefficients. On the other hand, while glass had been pressed in gypsum moulds, as already mentioned, there was no record of it having been done under conditions where the glass remained in the mould until cold. Also, with a mould material in use that was known to expand 1.25 per cent at 1200-1400 degrees, Fahrenheit, it was felt that this could also be the cause of some or all of the cracking. Finally, it might be due to the annealing method.

The first two of these possibilities remained unknown for some

time. The third one regarding the annealing was automatically eliminated some time later by the examination of a number of pressed cases with a polariscope. For this reason, the cooling technique has required no alteration. It has the disadvantage of being slow but as long as the process remains in the laboratory stage, it is sufficiently fast.

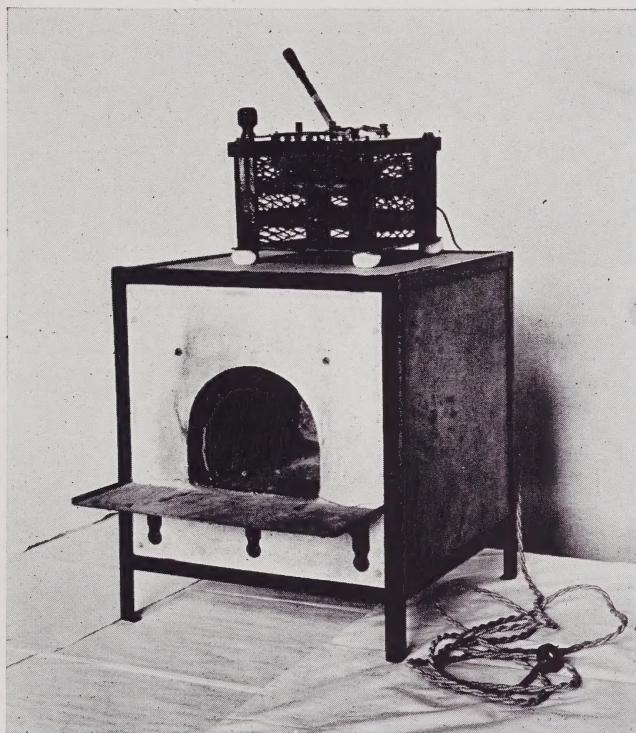


Fig. 9.—Early type of horizontal furnace.

A few months later, a furnace was constructed as illustrated in Fig. 9.

The sides were of transite bolted to an angle iron frame. The resistor was of "Chromel A" ribbon held in place by Aloxite cement. A rheostat on the top completed the electrical circuit. Sil-o-cel was used as thermal insulation between the element and the casing. A thermo-couple was installed through the back wall.

The difficulty with this furnace was that it incorporated no

provision for putting pressure on the flask. The procedure was to remove the door, put the end of an iron rod on the flask and pry against the top of the furnace opening. This was a hopelessly inadequate method for different reasons and a suggestion was welcomed that we have the glass company press a case in one of their machines.

Experiments with a pouring technique. A crucible of glass was placed in a "glory-hole" of a furnace and heated it to a consistency at which it would pour freely. A flask was pre-heated and the halves mounted in a press so they would be accurately assembled when the lever was lowered. A generous amount of glass was poured into the mould, clipped off with shears and the flask closed accurately and tightly with the lever. The flask was then removed and sent through the lehr to have the contents annealed.

Later, the case showed cracks and also bubbles but the method of closing had made an impression. It seemed so positive and accurate that the idea was at once incorporated in a discarded Taggart-type casting machine. A key-way fixed to the casting head, as in Fig. 10, and an undercut rib to fit this channel was fixed to a flask, as in Fig. 11.

The flask could now be pre-heated, one half quickly positioned in the casting head and the other rested on the platform directly below. Glass could be poured into the mould and the handle of the casting machine activated to put pressure on the flask and close it.

A large size furnace, Fig. 12, was secured from the Metallurgy Department to melt the glass. Several cases were put through with this equipment to definitely establish that the technique was unsatisfactory. The great trouble was that the glass had to be heated to a much higher temperature when it had to be poured. Thus, it was far beyond the temperature of the flask and the mould and it was felt that cracking of the glass and teeth could not be avoided. Finally, glass was poured in a cold mould and the result was so convincing that the method was given up. All teeth were hopelessly cracked and the glass broke into very small pieces as the mould was opened.

One point was certain. Regardless of any other factor that was causing checking, the temperature difference of mould and glass assuredly would. The only solution, apparently, was to have

mould and glass in the furnace together up to and during the processes of both pressing and annealing.

During all of this time, changes were being made in the mould material at irregular intervals in an effort to meet the demands of the technique. Good refractories are not rare but the best of them

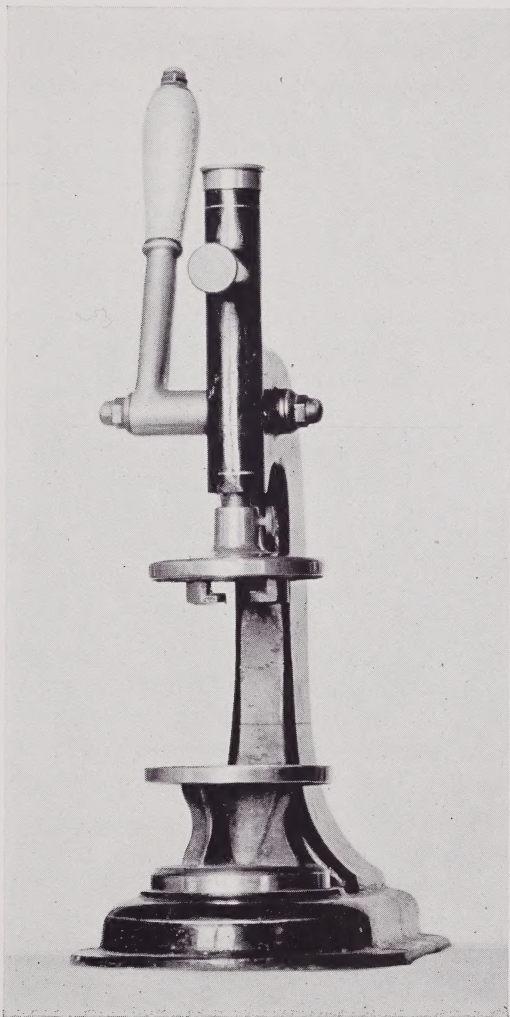


Fig. 10.—Taggart-type casting machine with attachment for holding flask fixed to the casting head.

must be pre-fired to bond them. This, of course, is impossible in dental technique. Our mould material must air-set quickly to a fairly hard condition and there should be as little volume change as possible both in the setting and heating of the mould. Under these conditions, the mould material will permit boiling out of the flask, exposure to the heat and the pressure required for closing the case.

Flask design was more or less at a standstill in the meantime. Fig. 11 shows that the broad hinge had been discarded. It had been found inaccurate because it permitted an increasing lateral movement. Also, glass got into it at times and the mould could

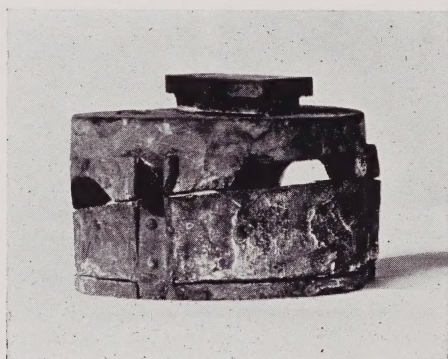


Fig. 11.—Flask with key-way to fit Taggart-type machine.

not be closed and, lastly, moulds could not be closed from the posterior in those cases with heavy anterior undercuts. Lugs were again resorted to and the policy was simply to use iron flasks of an obsolete pattern because of their cheapness and discard them when they were ruined. This continued for some time while work proceeded along other lines.

Experiments with a settling technique. It was next decided to put mould and glass into the furnace at the same time and attempt to fill the mould by a settling method.

A lower denture was waxed with a large sprue at each heel much in the same manner as for the cheoplastic work formerly familiar in dentistry.

The set-up was not placed vertically in the mould material. The carving of the wax does not always leave the crowns sufficiently

exposed to be well gripped by the mould material and the tendency is for some of the teeth to topple out of their positions into the mould. Any volume change in the mould material greatly increases this danger. To obviate it, the set-up was placed in the mould material with the teeth down and at an angle of about forty-five degrees to allow gravity to fill the mould with molten glass.

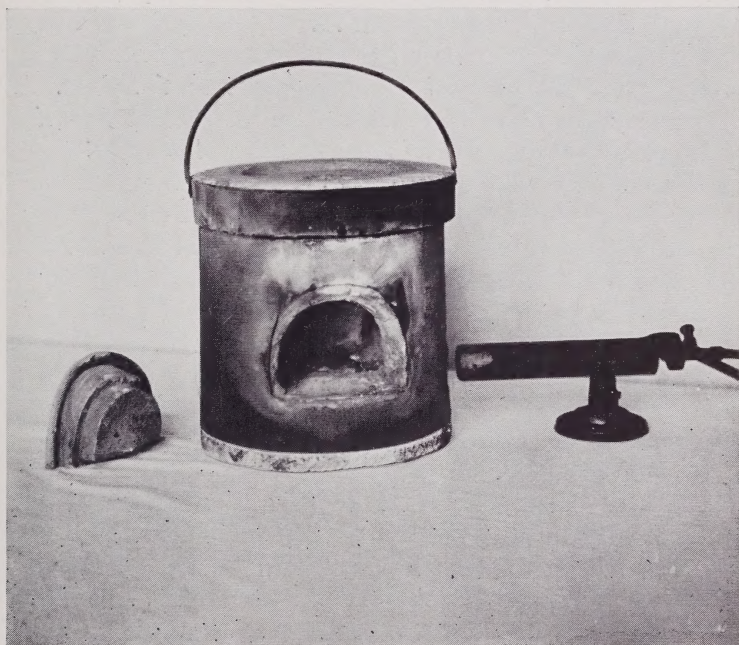


Fig. 12.—Large size Metallurgy Department gas furnace.

A split mould was constructed, separated and the wax eliminated. It was then re-assembled and surrounded with a heavy layer of mould material to hold the halves together. One gate was enlarged to form a crucible, or fount.

A type of glass, Code No. G 632-BE, was recommended not because of its coefficient which was considered too low but because it would flow at a much lower temperature and would save the mould material to a certain extent while the method was being tried out.

The mould was placed in a gas furnace with a heavy baffle to stop the direct blast of the heat.

A most welcome surprise awaited the opening of the mould: the glass had not cracked and neither had the teeth. This was quite unexplainable at the time. This glass, No. G 632-BE, was listed with a coefficient of 75 while the latest tests on the teeth had shown them as 88. However, experiment after experiment verified this observation until a re-check of the expansion of the teeth established their coefficient at 79. The adoption of this glass ended all trouble from checking until the coefficient was again altered by the addition of coloring agents to the glass. This further worry was also eliminated and at the present time, fortunately, checking in the teeth or glass is a thing of the past.

But there were troubles with this method. The heat was too great for the mould material. It gassed badly, cracked during the firing and adhered obstinately to the surface of the glass. Another feature was the undoing of the technique. Regardless of the carving and care in cleaning the wax from the coronal surfaces of the teeth to allow the mould material to grip them well, and regardless of the angle to which the mould was tilted, the hot glass was so adhesive as to literally tear tooth after tooth out of position in the mould and roll them along with the flow of glass until stopped by the shape of the mould.

As a means of correction, it was felt that instead of having several pieces of cullet in the fount to soften and flow down around the mould, the latter could be packed with glass of, say, thirty mesh that would simply melt and remain in position. In this way, there would be no flow to move the teeth. After quite a number of cases were fired, the method had to be given up for a most unforeseen reason. The texture of the glass was very poor even though the temperature was raised to 1100 degrees, Centigrade, in certain experiments.

Finally, the explanation became clear. Apparently, there is a great difference in the properties of the same glass dependent upon its form. Thus, when one begins with irregular pieces of properly fired glass, or cullet, they will soften, weld together perfectly and can be pressed to any shape with no sacrifice in quality of bulk. On the other hand, when one begins with properly fired glass of, say, thirty mesh, while welding again takes place because of solid mass results, the quality of the glass is very low. Apparently,

finely divided glass has to be re-melted completely to retain the quality of the individual pieces. Inclusion of air plays an important part because the bubbles are only expelled by a re-melt. This involves higher and more prolonged heat and the glass should be in such a quantity that convection will make the mass homogeneous throughout.

These conditions are not practicable in a dental mould and another method went into the discard. The time spent on the settling method had not been wasted however, because some very important information had been gained.

Development of a mould material. In addition to the above-mentioned point regarding the glass, the serious gassing of the mould under the increased heat had resulted in the development of a material that was not only almost non-gassing but was also practically inert and, therefore, withstood heat with very little cracking.

This combination was found to be sufficiently hard and with no apparent sacrifice of other necessary properties. It has continued in use until the present time.

Some mention should be made here of a point regarding the porcelain teeth because it was finally solved about this time. It was observed in each of many processed dentures that discoloration and bubbles occurred in the proximity of the metallic pins of the anterior teeth. Luckily, the seal of the glass to the porcelain was so perfect that pins were not required so they were cut off without regret. The trouble continued to a minor degree, however, until the pins were completely ground out. Since that time no bubbles have occurred.

Development of a furnace design. With the settling method in disfavour, a summary of the information at hand is in order inasmuch as it will explain the reason for the next move.

It has been established, for instance, that the mould and glass should be at the same temperature and that the surest and simplest way of assuring this condition is to have both in the furnace together during all of the firing period. Also, there is no critical point for processing to begin. On the one hand, the higher the temperature, the more easily will the glass move into position in the mould. On the other hand, a higher working temperature shortens the life of the resistor in the furnace, causes more oxidation of the flask and leaves the glass in the mould with a rougher surface due,

perhaps, to a slight disintegration of the adjacent mould material and the adhesion of it to the glass.

For these reasons, it seemed logical to fire the cases at a lower temperature and to use pressure to force the glass into the mould.

Accordingly, a furnace was designed with a vertical plunger that would exert pressure on the mould during the heating process. Fig. 13 is a sketch of this assembly. The resistor was composed of 28 feet of 16 gauge "Nichrome 4" wire held in place by Aloxite cement. Sil-o-cel was used as a thermal insulator between element and casing. The top was perforated, as shown, to permit the insertion of a vertical rod of one inch diameter to rest in a coupling

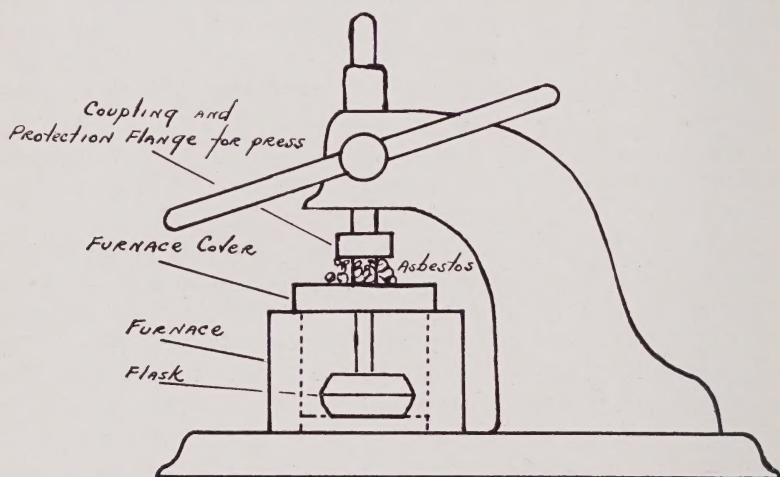


Fig. 13.—Furnace mounted on base of bench press.

on the upper side of the flask. A thermo-couple was also inserted. The whole was mounted on the base of a press so that pressure could be exerted on the spindle.

A gas furnace was constructed at the same time but it was immediately given up. The heat and noise were objectionable, the use of a single burner caused unequal heating of the mould, and the gas reduced the surface of the glass to a certain extent.

The furnace of Fig. 13 functioned well but, since it was only intended as a makeshift, it was replaced by that of Fig. 14. The essential difference in this furnace was the presence of the upper

structure to hold the spindle in position as it passed through the cover and rested on the top of the flask inside.

This upper structure proved to be in the way during operation and it was superseded by a removable arrangement, as illustrated in Fig. 15.

This was also awkward and the furnace was next used without it, as in Fig. 16. It was found that the hole through the cover

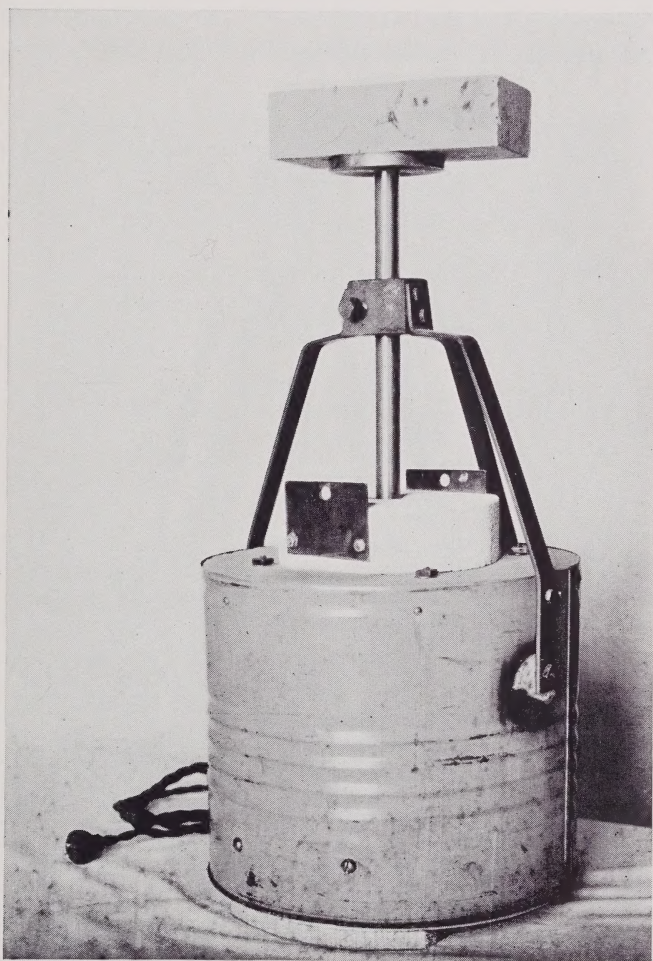


Fig. 14.—Pit type furnace with stationary upper structure to guide spindle.

held the spindle in sufficiently good alignment to make the framework unnecessary.

There was only one additional point. The placing of a weight on the spindle was rather crude and inefficient as well because it was difficult to ascertain the state of viscosity of the glass. For this reason, a furnace was fitted with a yoke and lever arrangement, as in Fig. 17. This yoke was found to be out of the way at all times and it was but the work of a moment to drop the spindle through to the flask, put the lever in position and pull down gently on it to detect any movement in the glass and, when present, to hang a

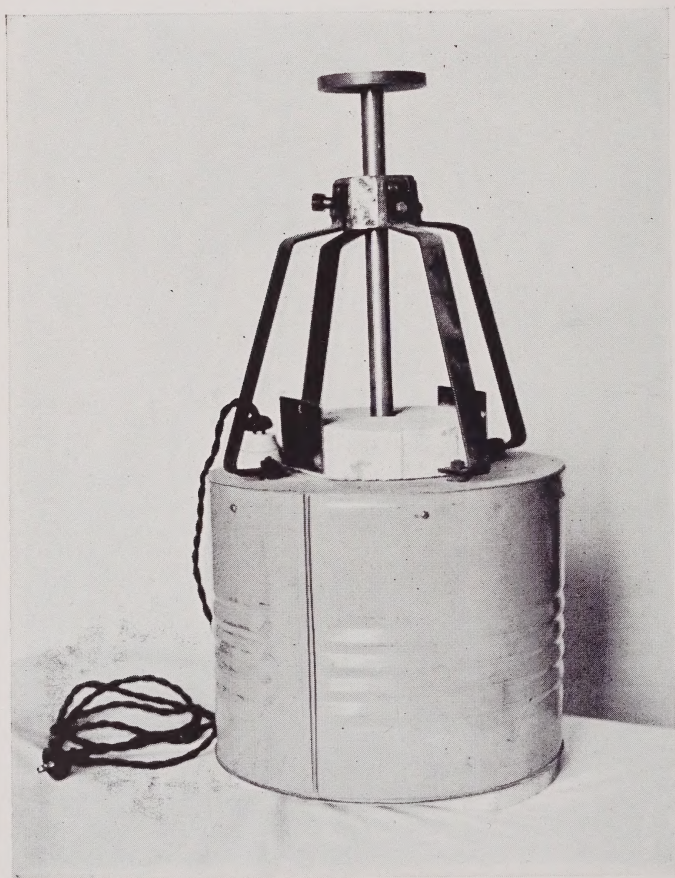


Fig. 15.—Pit type furnace with removable upper structure.

weight on the end of the lever. This design has proved so efficient that, with minor alterations, it has persisted to the present time.

Further development of a flask design. During these experiments a knowledge of the requirements of a satisfactory flask was being gained.

First, it was very plain that the alloy should not oxidize. Second, the bottom of each flask had dented badly because of the pressure of the spindle at red heat and it was realized that future flask construction should be reinforced to withstand this pressure. Third, there had been difficulty for some time in assembling the

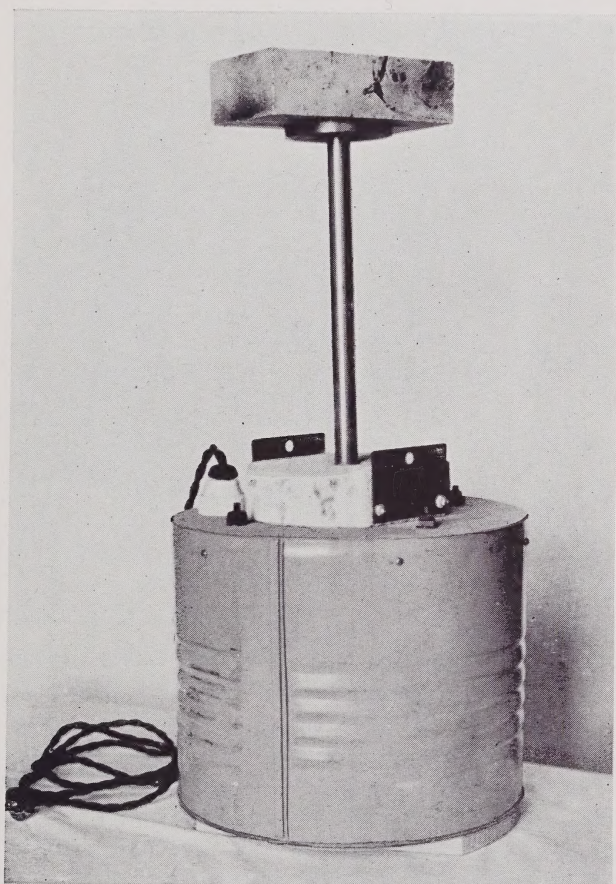


Fig. 16.—Pit type furnace with upper structure removed altogether.

flasks with sufficient glass in the moulds. The irregular shapes of the pieces of cullet increased the bulk of the glass required in the mould to such an extent that the halves of the flask were so far apart when assembled that the lugs could not engage their channels on the other section of the flask.

For a few cases, a certain amount of glass was presagged in the mould, in other words, the mould was filled and that part of the flask was fired to a point where the glass softened, welded into a



Fig. 17.—Pit type furnace with yoke and lever arrangement.

solid mass, and “sagged” about the teeth. The case was then removed from the furnace, more glass was put in the mould, the flask was assembled and fired again. This extra firing was an objectionable feature for different reasons and, as soon as possible, a flask was altered to have the lugs lengthened, as in Fig. 18.

Shortly afterwards, this was followed by another design shown open and closed in Figs. 19 and 20.

It was constructed of an alloy, Silal¹, with a formula as follows:

¹J. G. Pearce, A New Type of Heat Resisting Cast Irons, page 5.

Iron.....	90.67	per cent.
Silicon.....	7	" "
Carbon.....	2.32	" "
Manganese.....	.01	" "

This was known to resist oxidation to a great extent and to be comparatively easy to machine.

The size of the flask was increased to permit the operator a wider waste ditch about the cast. The shape was made circular for easier and cheaper machining.

The pins were increased to three in number and offset in arrangement to prevent incorrect closure of the flask. They were driven into holes in bosses in the centre section rather than rivetted to the



Fig. 18.—Trench type flask fitted with extra long lugs.

outside. The upper parts of them that went through the bottom section in assembling the flask were made triangular in cross-section to reduce the bearing area.

The thickness of the walls was increased and, in particular, the bottom was made considerably thicker to withstand the pressure of closing the flask at the working temperature.

The undercut button on the inside of the top can be noted in Fig. 19.

The bottom section was made as low as was advisable for the investing of the cast and the creation of a generous waste ditch. In this way, the cast was always high up and a correspondingly deeper mould was formed in the other section. Thus, the mould could be packed with an additional amount of glass.

Generally speaking, this flask was successful. The alloy resisted

oxidation well, as may be judged from Fig. 20, especially when it is explained that the photograph was taken after the flask had been through the furnace many times.

On the other hand, the thickness of the bottom was still not sufficient to withstand the pressure. Note the crack in the metal in Fig. 20 where it finally gave way.



Fig. 19.—Silal flask separated to show the three sections.

The holes through the centre section had to be cleaned out occasionally to guarantee easy closure during firing. Perhaps some future design may remove the outside wall of the hole but, so far, it has not been considered too much trouble to clean them.

The diameter of the pins was not sufficient. They bent during firing in a few instances.

Another point appearing many times during processing. The

flask as it sat on the bottom of the furnace was very difficult to pick up with the tongs and, for this reason, had to be rested on some sort of a small platform. This was corrected in the next



Fig. 20.—Silal flask assembled.

design by making this section of the flask thicker also and then cutting a shoulder on it at the periphery.

Finally, and perhaps more slowly because this flask was so satisfactory, a design was completed, as shown in Figs. 21 and 22.

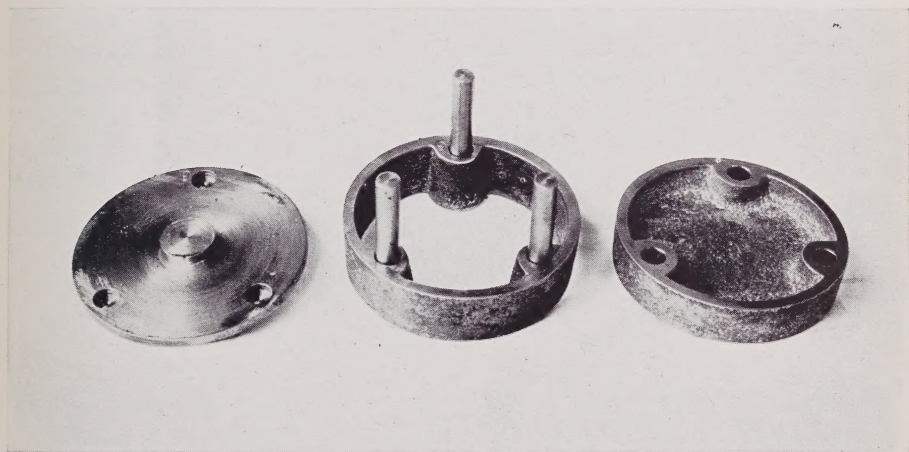


Fig. 21.—Various sections of the Nicrosilal flask.

The alloy in this flask is Nicrosilal, an undoubted improvement on the Silal combination. The formula is as follows:¹

Iron.....	71.20	per cent.
Total Carbon.....	1.80	" "
Silicon.....	6	" "
Nickel.....	18	" "
Chromium.....	2	" "
Manganese to.....	1	" "

All the good features of the former flask were retained and, in addition, the diameter of the pins was increased, the bottom was increased to double thickness, and the top cut similarly to allow the furnace tongs to grasp it.

This completes the progressive story of the development of the technique. It is the description of a meandering trail that has wound slowly through the construction of more than one hundred experimental dentures.

In addition, it was accompanied by the testing of more than sixty different glasses, the construction of eight flask designs, nine furnace designs and the use of over a dozen variations of mould material. If this description serves to some degree to render to the reader an explanation of the reasons for many of the steps in the present working technique and the peculiarities of design of the equipment, its purpose is fulfilled.

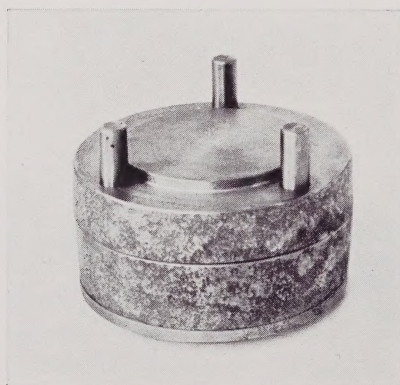


Fig. 22.—Nicrosilal flask shown assembled.

¹A. L. Norbury and E. Morgan, Silal and Nicrosilal, Heat Resisting Cast Irons, pp. 267-277.

CHAPTER IV

ELABORATION OF THE FINAL TECHNIQUE

Carry the construction of the denture up to and through the try-in stage in the same manner as for any other base material except for one point. It is imperative to have selected diatoric anterior teeth or to have completely removed the pins if the familiar vulcanite-type anterior teeth have been used.

Complete the waxing as far as possible exactly as the finished denture will be required to be. This has always been good technique because, obviously, the wax is easier to work than the processed base. However, all our denture bases to date have been fairly easy to trim and finish and, therefore, the tendency has been to wax to excess and to trim the base to proper contour after it has been processed.

The story is completely the reverse with glass. The material is so hard and the process of trimming is so slow as compared with the other materials that the operator is well advised to view his denture in the same light as an inlay pattern. In this latter case, he knows that a pattern waxed carefully as regards margins, contacts and bite means very little grinding of the inlay. Glass base technique is quite analogous. The glass takes the fine lines of the mould so perfectly that the operator is assured of an exact reproduction of his carefully carved denture pattern. In addition, the surface of the glass is such that, in the great majority of cases, it does not have to be trimmed at all. The surface of the mould imparts to it a most lifelike stippled appearance and it is only necessary after processing to clean the mould material from it with a nail brush and then allow the acid dip to completely finish it. Thus, the operator is very well repaid for extra time spent in accurate waxing.

Remove the waxed denture from the cast and the latter from the articulator.

Construct a duplicate cast in refractory mould material. A very simple method is by the use of an empty coffee or tobacco can. Select one about four or four and one-half inches in diameter, cut the bottom out of it and then reduce the length to about two inches.

To use it for the above purpose of duplicating a cast, place the top on it, sit it on the desk top down, wet the cast thoroughly and set it, base down, in the centre of the top.

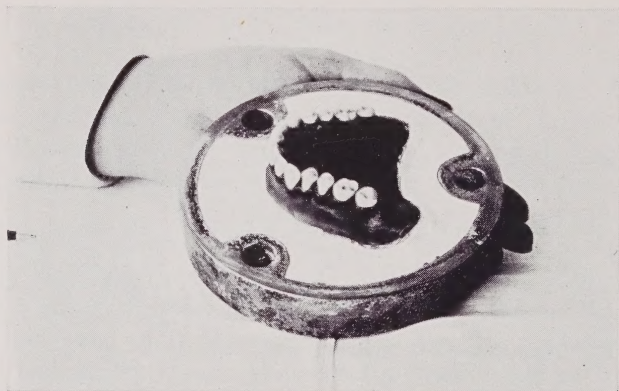


Fig. 23.—Side view of the waxed-up denture imbedded in the bottom section of the flask.



Fig. 24.—Posterior view of the waxed-up denture imbedded in the bottom section of the flask.

Prepare some used Dentocoll to a consistency considerably thinner than for use in the mouth and fill the can with it.

Chill the Dentocoll, remove the top from the can to expose the

base of the cast. Then remove the cast and pour the impression at once with a thick mix of refractory mould material.

Remove the impression material from the cast and seal the waxed-up denture on the latter.

Imbed the refractory cast and denture in a thick mix of mould material in the bottom section of the flask with the protection rim of the cast as even with the upper margin of the flask section as possible. This is well illustrated by Figs. 23 and 24. Casts with anterior undercuts should be flaked in a more vertical position to reduce the effect of this undercut.

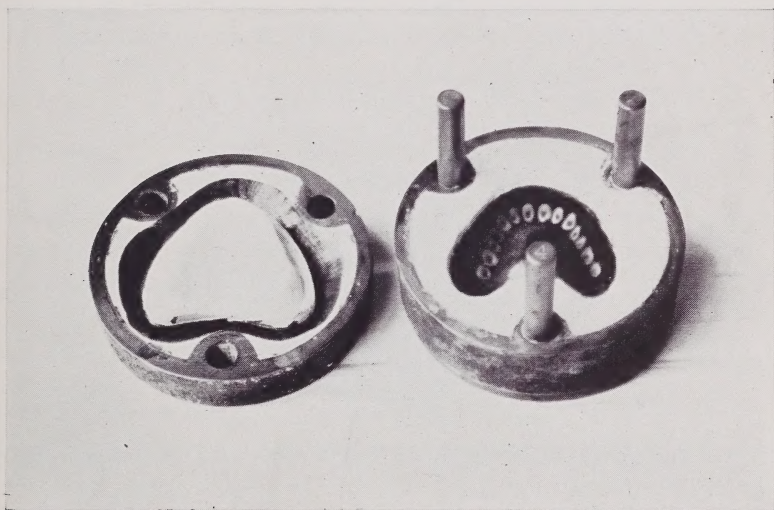


Fig. 25.—The flask showing the mould after separation. Note the waste ditch about the cast.

Allow the mould material to set, trim off the excess between the protection rim and flask and apply a separating medium to the exposed mould material.

Fit the middle section of the flask in position on the lower, fill the assemblage with another stiff mix of mould material and place the top in position.

Permit this second mix to set, then place the flask in boiling water for a few minutes to soften the wax. Open the flask and remove the wax. It is not necessary to use great care in the removal

of the wax. It is thoroughly eliminated by the heat of the furnace long before the processing temperature is reached.

Cut a deep ditch about the cast, as in Fig. 25, to take the excess glass during the pressing process. In this illustration, the waste ditch about the cast in the one section of the flask and the complete mould in the other section have been shellacked to increase the contrast for photographic purposes. In the actual technique, of course, the shellac is not used.

Dehydrate the two halves of the mould over low heat if time is available.

From this time on, the top and middle section of the flask which contained mould material and teeth will be known as the female part. The remainder of the processing is done with this part

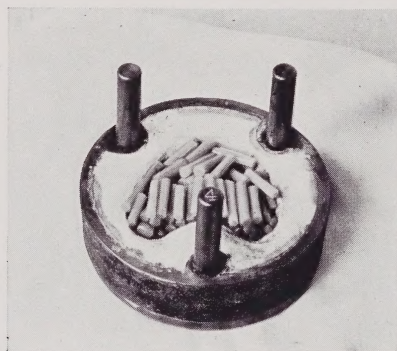


Fig. 26.—The female part of the mould packed with glass cane in short lengths.

downward. This procedure provides a cup-like depression in which to soften the glass and, at the same time, effectively prevents the teeth from falling out of the mould.

Pack the female section carefully with pieces of glass cane cut to suitable length. This is well illustrated in Fig. 26.

An operator's knowledge of the packing of moulds for other bases with the addition of a little experience in the use of glass will enable him to determine the approximate amount to place in the mould.

A comparatively accurate method of determining the weight of glass to be used is as follows: weigh the teeth before articulating them in the set-up and weigh the completed set-up in wax. Deduct the weight of the teeth and multiply the result by four to find the

weight of glass to be put in the mould. Often, however, the position of the glass in the mould is important because of irregularities in either part of the latter. For this reason, a certain amount of excess is necessary. However, avoid too great an excess because it only requires a more prolonged heat with consequent loss of time to the operator and longer exposure of the flask to oxidation.

Assemble the flask with the male part resting lightly on the surface of the packed glass in the female part, as in Fig. 27.

Place the whole assemblage in the cold furnace, put on the cover and turn on the heat. A cold furnace is advocated because the two halves of the flask have been only mildly pre-heated at best. If, however, the furnace is already hot, it will be necessary to pre-

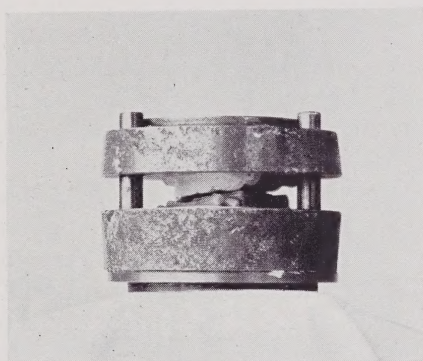


Fig. 27.—The flask assembled, male part resting lightly in position on the packed female part.

heat the packed flask to a temperature that will preclude the possibility of damage to mould material or teeth.

With the present type of furnace, when the glass is sufficiently fluid to begin pressing the denture place the vertical rod down through the hole in the cover to rest on the top of the flask. The reader is referred back to the type of furnace shown in Fig. 17. Make a mark on the rod that will aid in determining the distance the flask closes when pressure is applied to it.

Place the horizontal lever in position and suspend a weight on it. This has proven to be the best method to date because the viscosity of the glass allows the flask to close but slowly. Do not use too great a weight, the pressure may deface the mould. On the

other hand, too light a weight will not act before the fluidity has increased greatly with the higher heat and the flask has been exposed to more prolonged oxidation.

After a period of, perhaps, ten minutes observe on the vertical rod the distance the flask has closed and, if necessary, open the furnace, remove the flask and examine it. If it is not fully closed, replace it in the furnace and allow it to heat up again to a temperature at which it can be pressed completely down. In those cases where the flask is open a little more on one side than on the other, replace it in the furnace so the open section is below the vertical rod where it will receive most of the pressure.

There is nothing critical about this technique. Within a reasonable limit, an increase of heat only tends to increase the fluidity of the glass and render pressing an easier operation. However, the denture should be pressed at as low a temperature as possible because of the factors of time, exposure of the flask to oxidation, etc.

When the flask is completely down, replace it in the furnace, put on the cover, turn off the heat and allow the whole to cool down together.

Removing the denture from the flask, trimming and polishing. When the flask is almost or quite cold, open it and carefully remove the denture and attached excess glass. Generally speaking, this will cause very little trouble because the mould material is not hard or obstinately adherent to the surface of the glass.

Remove the large pieces of mould material from the denture with a pointed instrument, then clean the denture with a nail brush and water.

When a denture has been pressed fully down, the protection rim of the cast has thinned the junction of denture periphery and excess glass in the waste ditch to a fine layer that can be broken all round with a wax spatula to free the piece or pieces of excess glass. If, on the other hand, it is necessary to cut through this roll of excess, a saw of sheet iron, such as shown on the left end of the spindle in Fig. 28, is probably the best agent.

The trough above the saw holds water that runs slowly through the tube at any required rate to drip on the saw and glass at the point where the latter is being cut. The tin container at the end of the trough is filled with No. 90 emery powder that also runs down a tube to fall on the saw and mix with the water in the cut.

A motor on the base at the back drives the saw at a slow rate

of speed in order that local heating will not occur in the glass at the point where it is being cut.

Another method is to use a dental stone at a slow speed and with plenty of water or vaseline.

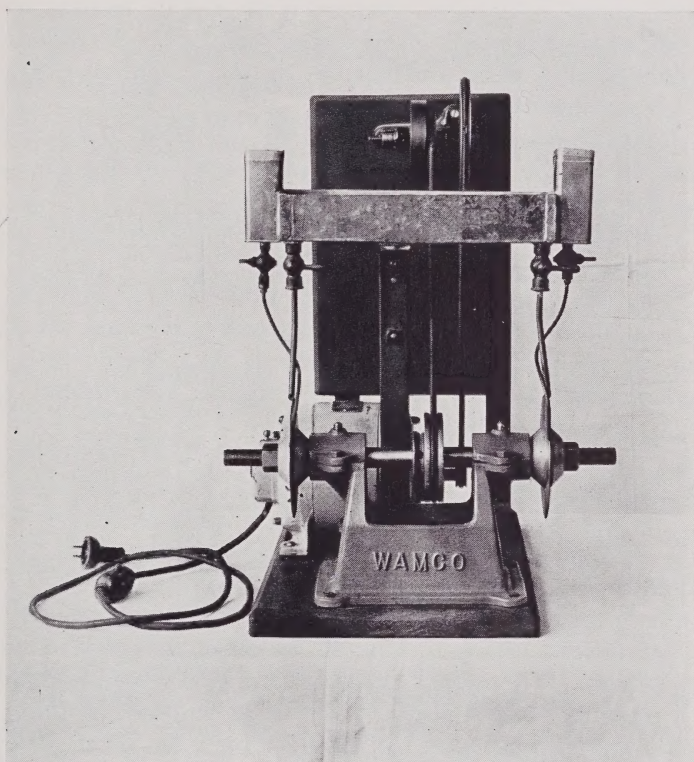


Fig. 28.—A slow speed apparatus made up for cutting and grinding glass.

Remove the ragged edge at the periphery and grind the margin to any desired shape by using the tapered, soft steel wheel shown on the right end of the spindle in Fig. 28. Again note the arrangement for feeding emery powder and water into the cut. To the author, this was one of the most interesting processes in glass technology. The ease with which it can be cut and ground by the two metal disks is simply amazing.

Give the denture an acid dip as the next step in preparing it for the mouth.

The acid solution consists of:

Hydrofluoric acid (60%)	3 parts
Sulphuric acid (comm)	1 part

Keep this solution in a small lead vat of just sufficient diameter to easily admit a denture. Prepare it for use by heating it to a temperature of about 130-150 degrees, Fahrenheit. A cold solution acts more slowly; on the other hand, too hot a solution will soften the wax on the teeth.

A fume chamber is not required for the acid unless a large amount of work is being done, however, avoid inhaling the fumes as much as possible.

Prepare the denture for dipping by painting the teeth with a layer of hard inlay wax.

Adjust the denture in a sling of lead wire, or similar, and immerse it in the acid for about seven seconds. Remove it and thoroughly wash off the obstinate white scum in warm water with the aid of a nail brush. Repeat this dipping and washing twice more for a maximum brightening effect.

This process leaves the denture with a smooth, matte surface that is highly satisfactory for the anatomical surface and, in certain cases, for the labial, buccal and palatal surfaces as well. The surface of the mould material is just sufficiently rough to create a most lifelike stipple on the surface of the glass.

There are cases, however, where a polish is advisable on the labial and buccal surfaces. This can be easily accomplished in the following manner: remove the marks of the steel wheel, or roughing mill, by a smoothing stone. This may be either a Scotch black cragleith or a Norton stone, No. 220-J. Run either stone at a slow speed with water dripping slowly on the cut.

Polish the smoothed surface with a buff or brush carrying pumice and water. This wheel must also run at low speed, perhaps a little faster than that used for the roughing and smoothing operations.

Secure the final brilliance with a slow speed buff using lead oxide and water.

This technique secures a finish that is really artificial because it fairly glitters. Full details are given as a matter of technique but it is left to the individual operator to leave off at any point where he considers the finish satisfactory.

CHAPTER V

SOME MISCELLANEOUS PROPERTIES OF GLASS

A glass is usually described in the handbooks of the company under five different headings. For instance, the glass that was modified for the present problem is charted as follows:

Code Number	Coeff. of Expansion	Softening Point	Annealing Point	Strain Point
G632-BE	75×10^{-7}	685 deg. C.	500 deg. C.	400 deg. C.

Thus, any elaboration of the properties of a glass can very well begin by an explanation of the above terms.

The code number refers to a filing system of the company and has no interest in relation to the present problem. The coefficient of expansion of a glass differs in no way from the coefficient of expansion of a metal and, therefore, requires no particular attention.

The softening point of a glass is defined by the company as that temperature at which a rod of the glass 23 cms. in length and .55-.65 mm. in diameter will elongate of its own weight in the furnace at the rate of 1 mm. per minute.

The term is no doubt a highly descriptive one to the company research department from a comparative standpoint but a further explanation is necessary for thorough understanding by the dentist.

It was learned as a result of the very first experiment that the viscosity of the glass was far too great for moulding at the so-called softening temperature. In fact, noticeable movement under a pressure sufficiently low that the mould material was not in danger of crushing began only at 900 deg. C. Since glass viscosity is approximately halved for every 25 deg. C. rise in temperature in this region, some idea can be gained of the great increase in fluidity that had to occur before a dentist would consider the glass soft.

The annealing point is usually defined as that temperature at which most of the strain in glass is relieved in from fifteen to twenty minutes.

No glass is ever absolutely free from strain but commercial annealing frees most of it in the following manner. During the time the glass is being processed to shape, or marvered, it passes quickly through the crystallization point. It may even pass beyond the annealing point as well. This makes no difference, however, because whether it is slightly above or below the annealing point when it is introduced into the annealing oven, or lehr, it is quickly brought to the annealing temperature and maintained there during the greater part of the annealing time of fifteen or twenty minutes.

At the end of the annealing time, the article is lowered very slowly at the rate of about 1 deg. C. per minute through the range down to the strain temperature. Scholes¹ gives a very fine explanation of the above points in his recent book.

Below the strain point, cooling can proceed at any rate short of causing breakage.

The whole story is one of viscosity, of course. As the article is maintained at the annealing temperature, it becomes very evenly heated throughout. This condition eliminates practically all strain. Then the article is lowered in temperature to the strain point at a rate so slow that no new strain will be introduced.

During this period, it may be considered that the inside layer of glass is sufficiently fluid to move and the annealing method described simply prevents the possibility of the outside layer shrinking faster than the inside.

Below the strain point, the inside layer is too viscous to move and, therefore, greater liberties can be taken with the cooling process.

The strain point can then be defined as that point beyond which glass is too viscous to easily permit the introduction of strain.

From the standpoint of practical working conditions with small electric furnaces, there is other information available.

In none of the experiments has strain due to faulty annealing caused the slightest worry and in none of the cases processed in clear glasses and later examined with the polariscope has any trace of strain been found. The annealing method was very simple. When the flask was finally fully closed, the furnace switch was opened, the cover left on the furnace and the whole allowed to

¹Samuel R. Scholes, *Modern Glass Practice*, pp. 191-201.

cool down together. As a laboratory technique, this left nothing to be desired but in a busy dental practice or a commercial dental laboratory a faster method would be necessary.

Crystallization. Sometimes in working glass in a flame, a spot of white scum appears on the surface. This is really an area of devitrification and is the result of silica or silicious compounds coming to the surface and leaving a matrix high in alkali and higher in expansion than the original glass.

There is a temperature region where, as glass cools, there is a tendency to devitrify, or crystallize, in spite of thermal agitation due to molecular activity on the hot side and viscosity on the cold side. And further, there seems to be a point where these two factors are so balanced that, if the glass is held there for any length of time, crystals will form.

Ordinarily, glass is heated up through this crystallization point and cooled down through it too rapidly for crystal formation. On the other hand, if crystals are present by some mischance, the glass should be re-melted to dissolve them and then cooled more rapidly.

CHAPTER VI

DISCUSSION OF THE PROPERTIES OF GLASS IN COMPARISON WITH THOSE OF THE IDEAL DENTURE BASE

With the knowledge gained of the properties of glass and the technique for its use as a denture base, it may well be considered next in order to make some comparisons with the ideal base, also previously described.

Color. It is felt that the color satisfactorily matches that of gum tissue for the great majority of patients. The accuracy of the selection and its superiority over that of vulcanite remain open questions awaiting the answer of each individual operator.

The great quality of this color combination in glass is the stability of it, however. To begin with, it is established in the glass by thoroughly incorporated metallic oxides and nothing except a re-melt will alter it. Since processing a denture merely requires softening the glass, there is still a safety zone of several hundred degrees, Fahrenheit, that, as a matter of fact cannot be crossed by the furnace employed. This is equally true of re-processing, as in the repair and alteration of dentures. One denture, for instance, was thus altered four times with no apparent change in color from a control piece from the first firing. Thus, color insofar as glass dentures are concerned may be regarded not as a fleeting, critical property but rather as a foolproof one. So well does this condition hold, in fact that glass from the waste ditch of one processed denture can be thoroughly cleaned of mould material and used in the next denture with no discernible demarcation line. This is an altogether new property in a base that will result in pleasing economies to the dentist.

Glass is sometimes quoted as the most enduring material in the world and always it has been colored. One has only to think, for instance, of the colored glass in old church windows. In restoring them after hundreds of years, it has been found that breakage has occurred and the lead has failed but no charge of loss of color or other quality of the glass is laid by the authors reporting the information. On the other hand, there is no doubt but that glass is affected by agents, such as pure water and alkalis,

but the action is so very slight that it may be fairly placed at zero for the lifetime of a denture.

In a denture base material, this means that before being processed, no precaution will be necessary to keep it dry and cool and away from light. After processing, whether in the mouth or out, in the sunlight or out of it, no effect will become apparent during the lifetime of the patient; in fact, after years of use by one patient, it should be perfectly practicable to break up the base and use it to form part of a new denture.

No content in the saliva or orally administered drug is known that will affect it. Likewise, no disinfectant solution into which it may be placed will alter it. Without doubt, glass is decidedly superior as regards this highly desirable property of color stability; in fact, it seems to be almost the ultimate for our dental purpose.

Translucence. As a quality, translucence is practically at its maximum in a glass denture base.

During the development of the glass, certain batches were made with much greater translucence but it was immediately observed that the necks of the teeth were objectionably apparent. Therefore, the opacity had to be increased to a point where the underlying porcelain could not be seen.

Dental opinion usually grants that translucence is a very desirable quality in a denture base. However, it is apparent from the above that a very slight amount is all that can be tolerated and that glass possesses it almost to perfection.

Vulcanite, on the other hand, is characterized by a dead opacity that has been the subject of criticism ever since the introduction of it into dentistry.

Stability. The points just discussed regarding the permanence of the color are equally true of glass generally.

Mechanical disintegration and chemical decomposition due to heat, moisture, light and drugs simply do not occur, at least, within many years. In this respect, glass is even superior to porcelain where surface cracks may be present or where it has been necessary to remove the glaze in relieving the periphery or other parts.

Hardness. One of the popular questions by a dentist regarding a base material is an enquiry as to whether it will take and maintain a high polish. The quality of hardness is important in this connection. A quotation from a technical booklet by a glass company

states the case very well as to the hardness of glass.¹ "The surface hardness is but three points below that of the diamond and the exceptionally smooth, nonporous, outer skin will resist certain kinds of abrasion even better than will a surface of steel."

A most beautiful polish can be given a denture without great difficulty; in fact, it seems so superior to the requirement that it advertises itself by its winking brilliance. For this reason, very little mechanical polishing is done and this is confined to labial and buccal flanges. The acid polish is sufficient in the palate.

The permanence of this polish is of a high order not only because of this extreme hardness but because also of the stability and imperviousness.

Truly, vulcanite is no match in its ability either to take or maintain a high polish.

But there is a possible disadvantage in this extreme hardness because it is accompanied by a brittleness and a consequent low value of impact strength that may seriously affect its use in dentistry. This point is discussed later under the heading of strength.

Specific Gravity. The density of this particular glass is 2.5. This is for comparison with pink vulcanite at 2.30-2.60 and red, maroon and dark elastic at from 1.15-1.19. This means an increase in weight of a denture of, perhaps, 30 per cent., probably a difference of 3-4 dw't. in an average case.

It is the opinion of the author and one borne out by the test cases to date that this feature will cause no trouble in the great majority of cases. As an example, one extremely thick lower glass denture comes to mind that has been worn for well over a year without comment on this feature. However, there might easily occur cases where an operator might be obliged to consider it.

A further feature of the density of glass is its homogeneity. The surface does not crack or craze as does that of glazed ceramic materials and moisture and deposits can, therefore, secure no foothold. To this quality, add those of stability and hardness and the result is a base of unrivalled impenetrability.

Vulcanite is, therefore, 30 per cent. less in weight but very inferior as regards imperviousness. One has only to think of the initial porosity of much of the vulcanite and the deterioration of all of it with use to rate it much below glass in this quality.

¹Corning Glass Works. Physical Characteristics of Pyrex Ware, p. 4.

Strength. The strength, as has already been stated, should be adequate for all dental requirements.

Rational design of any construction must take into consideration: first, the external forces to be resisted, transformed or transmitted; second, the resulting internal forces; third, the mechanical properties of the materials to be employed.

There are two solutions to the problem of the external forces as applied to a denture base.

In the first place, vulcanite has been constantly used as a convenient basis of comparison up till the present time. Its properties are so well known to the profession that firms introducing new materials have in nearly all cases been content with describing certain properties of them by a comparison with the corresponding properties of vulcanite. Since any operator will agree that the



Fig. 29.—Gnathodynamometer in position in the mouth.

strength of vulcanite is satisfactory even though it diminishes with age, any material that approximates it is immediately regarded as acceptable.

This method of comparing a base with vulcanite is especially used by the manufacturer of a new base when the result is in favour of his material. This is, perhaps, unfair to the vulcanite. But there are also occasions when such a comparison may be unfair to the new material. For instance, a test may show it as distinctly inferior to vulcanite but this fact should not condemn it by any means. Vulcanite may exceed the mouth requirement many times and the inferior value of the other material may also easily surpass it.

Such an example is impact strength in glass. It is admittedly inferior to vulcanite but it may not be a serious disadvantage if it still exceed the mouth requirement by a sufficient margin. It would be just as unfair to draw attention to the tremendous superiority of glass in compressive strength, for instance. The strength of vulcanite in compression is ample for mouth use and the fact that it is below that of glass does not constitute a disadvantage by any means.

For such reasons, there is certainly a place for the second method of finding the value of the external forces. This is by determining the mouth requirement when possible.

Pressure in pounds exerted by a full denture against				
	High		Low	
	Ant.	Post.	Ant.	Post.
Natural Teeth	8	28	0	12
Fixed Bridge	6	24	0	12
Tooth Bearing Saddle	6	30	0	12
Tissue Bearing Saddle	8	24	0	0
Full Denture	20	44	0	6

Fig. 30.—Table of results of gnathodynamometer tests.

Some valuable information regarding the compressive force exerted on full dentures by various types of patients was gained by the use of the Haber gnathodynamometer, as shown in Fig. 29.

To secure a reading with this instrument, the patient is invited to bite on the blocks, as illustrated, and an arm registers the value on a scale.

Registrations were taken of many mouths and co-ordinated in Fig. 30. A glance at this table shows that the force exerted by a patient on a full denture base may vary from 44 lbs. in the posterior of the mouth to 0 lbs. in the anterior.

Stress produced in a body may be of the following varieties depending upon the arrangement and direction of the applied external force:

1. Tensile
2. Compressive
3. Shearing
4. Bending
5. Torsional
6. Combinations of the above

Some of the physical properties of glass may now be described to compare it with other bases and to form some idea of its suitability for dental use.

The following statement by Dr. Sullivan¹ with regard to the tensile strength of glass is very informative: "The tensile strength of glass in laboratory measurements ordinarily is about 10,000 lbs. per square inch, which means that, provided the laboratory strength could be maintained in large scale tests, a freight car and its load, 40,000 lbs., could be suspended from a glass bar two inches square. It is possible to prepare glasses by special heat treatment, the so-called case-hardening process, of tensile strength near that of wrought iron, which is about 50,000 lbs. per square inch."

The crushing strength is also tremendous. The same article by Dr. Sullivan states that²: "The resistance of glass to crushing pressure is very great. Provided again that laboratory measurements held good in large scale operations—which, of course, they do not—350 tons, eight loaded box cars, for instance, balanced on a two inch cube of the strongest glass might be just sufficient to

¹E. C. Sullivan. Glass Characteristics, p. 1.

²*Ibid.*, p. 2.

crush it. The compression strength of glass is greater than that of ordinary structural materials such as granite, concrete or vitrified brick. Even cast iron yields under three-fourths the pressure required to crush glass. In general, glass maintains its shape under pressures which cause metals to flow like putty."

How tremendous are these values as compared with the results of the gnathodynamometer tests already tabulated.

But for all this enormous strength under compression, the ability of glass to withstand impact is relatively low.

This is an important dental requirement for two reasons: first, a denture in the mouth may receive an accidental blow and, second, it may slip out of the hands of the patient while it is being cleaned and strike the basin or floor.

Fractures of a denture base due to the former cause are rather rare. Experience has shown that, excluding the occasional fracture of a porcelain tooth, it takes a heavy blow to break a denture base in the mouth. Under such conditions there is very likely to be much damage to facial and oral tissues and the failure of the base is not objected to. However, it is a noteworthy point that this possibility of breakage in the mouth promptly occurs to many patients when the use of glass as a base is suggested to them. The prospect of a mouthful of glass as the result of an accident seems horrible to them and, yet, the same patients may be wearing eyeglasses just as likely to be driven in pieces into the eyes under the same circumstances.

At the present time, advertising has made patients feel that a base should be unbreakable. It was of no consequence to the manufacturer concerned that irremediable distortion would occur in his base under the conditions specified; regardless of these other consequences, the ability of his base to withstand fracture was exaggerated to a maximum. But, after all, the thinking patient will realize that a denture is no stronger than its weakest component. Thus, a base with a value of compressive impact at least equal to the porcelain of the teeth will be satisfactory for all ordinary dental requirements.

Fractures of a denture base due to falling from a patient's hands are quite common in comparison to the intra-oral breakages just discussed. Comparative tests of glass and other current denture base materials are being made but the difficulty of suitably approx-

imating the correct type of load is such that the test of service will be resorted to mainly. With this in mind, dentures are being constructed for patients and the results recorded on questionnaires such as that shown in Fig. 31. This is felt to be good procedure for, regardless of all possible comparisons, the test of service will furnish the most conclusive information of the behaviour of the base under actual conditions.

Thermal Conductivity. The ability of glass to transfer thermal changes is of a high order.

Dr. Sullivan in describing the use of glass dishes for baking, etc., states¹: "Heat conductivity, of course, is far below the metals. However, in consequence of surface conditions heat transfer through a copper condenser is only two and one-half times that through a Pyrex condenser."

Thus, although the heat conductivity value of glass is only rated as .3 per cent. that of copper, the reflecting power of the former is so low comparatively that it practically overcomes the great advantage of the metal in this regard. It is, therefore, far superior to bakelite, vulcanite, etc.

Welding Ability. This property is almost at perfection in glass.

In the first place, a denture can be made of any number of pieces. These weld into a perfectly homogeneous mass in which no demarcation lines are visible. Further, the glass welds perfectly to the teeth. Sections cut from experimental dentures of clear glass showed a true wet seal under the microscope. So efficient is this union that no pins or undercut depressions are required in the teeth for anchorage. This is a very important feature from the standpoint of economics in the dental office because the cost of artificial teeth could probably be lowered considerably as a result.

In the repair of a denture no dove-tails or other preparation of the pieces are required. A clean fracture can be repaired by simply preventing any of the mould material from penetrating the crack during flasking of the case and then processing it at the correct temperature. Repairs with deficient spots are waxed without undercut of any kind and flaked. Glass is packed in the deficient spots after separation and the case is processed as before. Not only will there be a perfect union of the pieces but no demarcation line of any kind will be apparent.

¹E. C. Sullivan. The Many Sidedness of Glass, p. 177.

Relining of an ill-fitting denture, a process given up for the reason that rubber cannot be vulcanized out to a feather edge, will again be possible because glass will weld in sections of any degree of thinness and with no apparent junction line.

There is no doubt of the decided superiority of this property of glass over materials that require dove-tailing, tin foiling, show junction lines or that refuse to join at all.

Elasticity. This is a totally different property in glass than in some of the other denture bases. Such a hard, brittle material cannot be expected to show much deformation between the elastic limit and the ultimate strength. Scholes¹ gives the elasticity as about .1 per cent. and the Young's Modulus as 10^7 lbs. per square inch. On the other hand, its enormous strength in compression and tension guarantee that any intra-oral load will be well within the elastic limit. This condition is quite satisfactory because the author does not agree that dentistry requires a base that will yield readily or that will be permanently deformed, by any intra-oral force.

Odour and Taste. Both of these disadvantages are absolutely lacking in a glass denture. This is a wonderful feature because there are many protests on the characteristic odours from some of the other bases.

Working Properties. These are all that could be desired. The technique is practically identical to vulcanite during the flasking, boiling out and packing processes. It is more rapid in that the last vestige of wax does not have to be removed from about the teeth and the mould can be packed in a fraction of the time required to pack and test rubber. Also, no tin foiling is necessary.

Pressing technique is simple and certainly not critical. Removal of the mould material from the finished denture and polishing are extremely fast and easy.

Repairs and alterations, as already discussed, present little or no difficulty.

Altogether, the technique is certainly no more difficult than any other single technique in use at the present time.

Coefficient of Expansion. The very low rate of expansion of glass is a very desirable feature. The great volumetric change of rubber during vulcanization has resulted in numberless inferior dentures because of lack of care on the part of the operator.

¹Samuel R. Scholes. Modern Glass Practice, p. 238.

Not only is the coefficient of glass extremely low but the fact that it matches the coefficient of the teeth makes possible a true wet seal with the porcelain that precludes the penetration of bacteria, etc., and renders the denture completely impervious.

Conclusion. From the foregoing discussion, there seems to be no doubt but that glass possesses many fine qualities for use as a denture base. With the possible exception of impact strength, it appears to be quite superior to anything available to the dentist at the present time.

CLINICAL RECORD SHEET—DENTURE RESEARCH

Name and Address of Dentist.....

Name of Patient.....Diary No.....

Address.....Date of Insertion.....

Denture Description. Details as to type and condition of ridge—make of teeth—hard area—labial flange—miscellaneous.

Reactions of Patient and Dentist. Details as to colour—adhesion—thermal conductivity—weight—hygiene—tissue changes—miscellaneous information.

Fig. 31.—Copy of questionnaire accompanying each experimental denture inserted in the mouth.

SUMMARY

In the foregoing pages, the author has attempted to give a complete and yet concise description of his activities in the adaptation of glass for use as a denture base.

The requirements of the ideal base were first given to establish the criterion.

The author then chose to diverge and relate more or less as a narrative, the many steps by which the technique and supplies were slowly developed. To quote from the conclusion of one of the chapters "it is the description of a meandering trail that has slowly wound through the construction of more than one hundred experimental dentures. In addition, it was accompanied by the testing of over sixty different glasses, eight flask designs, nine furnace designs and the use of over a dozen variations of mould material."

The most recent technique was then elaborated because of the interest it must necessarily hold for any one who wishes to construct a denture of glass.

Finally, the properties of glass were impartially compared with those of the ideal and other current bases.

It is the hope of the author that it will prove of some small value in the practice of dentistry.

And what of the future may be asked? There are so many unsolved problems that the author feels that the present work should be submitted more or less as a progress report. Help is needed for the perfecting of the technique, equipment and supplies, the invasion of the field of partial denture prosthesis and other problems that might easily come to mind. To all those who like to pioneer the way, the subject of the use of glass in denture prosthesis is suggested as a very worthy one.

BIBLIOGRAPHY

SCHOLES, SAMUEL R. *Modern Glass Practice*. Industrial Publications, Inc., Chicago, 1935. Toronto Reference Library No. 666.1.S17.

A very practical book on formulae, properties and general technology of glass.

HODKIN, F. and COUSEN, A. *A Text of Glass Technology*. Constable and Co., 10 Orange St., London, W.C., 1925. Toronto Reference Library No. 666.1.H57.

A very fine work. Physical properties very well described, also, manipulation, annealing, etc.

The description of paste moulds and pressed ware especially good.

Encyclopaedia Britannica. Vol. X, 14th edit., pp. 398-420.

SULLIVAN, E. C. *Glass Characteristics*. Corning Glass Works Reprint. 1929. Descriptive reprint on the properties of glasses.

SULLIVAN, E. C. *The Many Sidedness of Glass*. Industrial and Engineering Chemistry, Vol. XXI, Feb., 1929, pp. 177-185.

Fine article on the properties and the field of usefulness of glass.

Corning Glass Works. Physical Characteristics of Pyrex Ware. Company literature, pp. 12.

Physical properties of glass.

TOOL, A. Q. and VALASEK, J. *Concerning Annealing and Character of Glass*. Bulletin of Bureau of Standards, Vol. XV, 1919-20, pp. 537-571. Toronto Reference Library No. 508.U.538.

Much useful information on annealing temperatures and characteristics of glass in that region. Also deals with annealing time, cooling procedures, etc.

LEHMANN, HELEN MARY. *Glass and Glassware*. Ronald Press Co., New York, 1922. Toronto Public Library, No. 658 M.

Raw materials, manufacture, finishing, polishing, engraving, etching, etc. Methods and types of decoration. Also, a fine historical sketch. Written from salesman's point of view but very instructive.

ROSENHAIN, W. *Glass Manufacture*. Constable and Co., 10 Orange St., London, W.C. 2, 1919. Toronto Reference Library No. 666.R-59.11.

Physical and chemical properties, raw materials, furnaces and melting methods. Chapters on Blown and Pressed Glass, pp. 116-128; Coloured Glasses, pp. 176-196; Chilled Glass, Rupert's Drops, pp. 236-7 are especially interesting.

BISER, B. F. *Elements of Glass and Glass Making*. Glass and Pottery Publishing Co., Box 555, Pittsburgh. Toronto Reference Library No. 666.1-B39.

Raw materials, properties, formulae, etc. Section on coloured glass was quite instructive.

PELLATT, A. *Curiosities of Glass Making*. David Bogue, 86 Fleet St., London, 1899. Toronto Reference Library No. 666.1-P25.

One of the older books but with interesting description of ingredients, manipulation, etc.

LEWIS, J. SIDNEY. *Old Glass and How to Collect It*. T. Werner Laurie, Ltd., 30 New Bridge St., London, E.C., 1925. Toronto Public Library No. 748-L674.

General superficial work on properties and constituents. Techniques are very interesting. Good historical sketch.

DILLON, E. *Glass*. Methuen and Co., 36 Essex St., London, 1907. Toronto Public Library No. 748-D38.

A hobbyist's book but beautifully illustrated through 373 pages. Contains no technology but is exceedingly stimulating.

MARSON, P. *Glass*. Pitman and Sons, 1 Amen Corner, London, E.C. University of Toronto Library, No. TC-Mar.

Short work on history, materials, chemistry, melting methods, manipulation, annealing.

ROHAN, THOMAS. *Old Glass Beautiful, English and Irish*. Mills and Boon, Ltd., 49 Rupert St., London, W. 1, 1930. Toronto Public Library No. 748.R737.

Really a collector's book but very instructive from the standpoint of accomplishment in glass manufacture.

LE COUTEUR, JOHN DOLBEL. *English Mediaeval Painted Glass*. Society for promoting Christian Knowledge. Toronto Public Library No. 748.L468.

Deals with technology of making a stained glass window; cutting, painting, firing, assembling, subjects, etc.

EDEN, F. SIDNEY. *Ancient Stained and Painted Glass*. University Press, Cambridge, 1913. Toronto Public Library No. 729-E22.

Traces the various periods and gives many illustrations. Very stimulating as regards the effects that can be secured. Contains no technology.

WHALL, C. W. *Stained Glass Work*. Pitman and Sons, Reprint 1920. Ballantyne and Co., Ltd., London. Toronto Public Library No. 748W.

Technology of cutting, painting, firing, leading. Chapters on color, imagination and design. A highly instructive work.

MUNSELL, ALBERT HENRY. *Book of Color*. Munsell Color Co., Baltimore. Dental Library No. 535 M 969.

A very complete description of an accurate method of checking and duplicating colours.

WARAN, H. P. *Elements of Glass Blowing*. G. Bell and Sons, Ltd., London, 1923. University of Toronto Library No. T.T. War.

A concise treatise of slightly over 100 pages on the general practice of glass blowing.

SHENSTONE, W. A. *The Methods of Glass Blowing and of Working Silica in the Oxy-Gas Flame*. Longmans, Green and Co., London, 1907. University of Toronto Library No. T.T. She.

A short, practical work on glass and how to handle it in a flame. Deals principally with the construction of apparatus.

HODGEN, JOSEPH D. *Practical Dental Metallurgy*. Revised edit. C. V. Mosby Co., St. Louis, 1919, pp. 436.

Properties of metals information especially useful.

NORBURY, A. L., and MORGAN, E. *Silal and Nicro-Silal—Heat Resisting Cast Irons*. Transactions of the American Foundrymen's Association, Vol. XLI, 1933, pp. 267-277.

Properties, formulae and other information on these two alloys.

PEARCE, J. G. *Recent Developments in Cast Iron and Foundry Practice in Great Britain*. Paper No. 486 presented at the 28th Annual Convention Institute of British Foundrymen, June, 1931. Reprint by Harrison and Sons, Ltd., London.

Properties and other information on Silal.

PEARCE, J. G. *A New Type of Heat Resisting Cast Iron*. Research Report No. 89 of the British Cast Iron Research Foundation.

Description of Silal—formula, properties, &c.

MOND NICKEL CO., LTD. *Nicrosilal, a Special Heat Resisting Alloy Cast Iron*. Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.

Description of Nicrosilal; properties, formula, etc.

A Liquefying Amylase in Human Saliva, Amylopectin, and Dental Caries

BY

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S.

*Research Professor of Periodontology
Faculty of Dentistry, University of Toronto*

RESEARCH CONDUCTED AT THE
FACULTY OF DENTISTRY
UNIVERSITY OF TORONTO

BULLETIN NUMBER TWENTY-FOUR

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

December, 1938

A Liquefying Amylase in Human Saliva, Amylopectin, and Dental Caries

BY

HAROLD KEITH BOX, D.D.S., PH.D., F.R.M.S.

*Research Professor of Periodontology
Faculty of Dentistry, University of Toronto*

RESEARCH CONDUCTED AT THE
FACULTY OF DENTISTRY
UNIVERSITY OF TORONTO

BULLETIN NUMBER TWENTY-FOUR

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

December, 1938

PART I

HUMAN SALIVARY REACTIONS IN THE ORAL VESTIBULE AND ORAL CAVITY PROPER

HAROLD KEITH BOX, D.DS., PH.D., F.R.M.S.

The oral cavity in the human is comprised of two main parts, an outer section called the vestibule and an inner division known as the oral cavity proper. When the teeth are normally present and in contact in centric occlusion, the crowns together with the roots and their supporting structures constitute a partition which separates the vestibule from the oral cavity proper. The oral cavity, strictly speaking, is not a true cavity when the mouth is closed at rest. Then, the tongue comes in contact with the walls of the oral cavity proper on all sides with the exception of the posterior part where an open space occurs. The vestibule also does not exist normally as a space, as the mucous membrane of the lips and cheeks rests upon the crowns of the teeth, the gingivae and the alveolar mucosa.

Into the oral cavity, numerous glands pour their secretions, some into the vestibule and others into the oral cavity proper. These are known as the salivary glands, and their secretions are called saliva. The smaller glands appear to function continually and thus keep the oral mucous membrane moistened and lubricated. In the larger glands, the salivary glands proper, in normal life, secretion is brought about reflexly in response to various stimuli. Certain stimuli exert their influence upon the peripheral endings of the sensory nerves of the mouth to produce secretion (the unconditioned or inherent reflex). Others act, not on the nerves of the mouth but on one or other of the organs of special sense e.g. sight and smell (the conditioned or acquired reflex).

THE ORAL VESTIBULE

When the lips are closed, they form, with the cheeks, the outer wall of the vestibule. The surface of the inner wall comprises the labial and buccal surfaces of the crowns of the teeth, the gingivae

and alveolar mucosa when the teeth are in centric occlusion. The general configuration is therefore determined by the dental arches. The two walls are in contact when the vestibule is not distended. Preiswerk (1) has pointed out the peculiarity that in mastication,

TABLE I.

PATIENT	left para- tid	Right Para- tid	Inf. Sub- Max	Rt. Sub- Max	left Sub- lingual	Right Sub- lingual	Soft Palate
I	6.0	6.0	7.5	7.5	6.8	6.8	6.5
II	5.8	6.0	7.5	7.5	7.5	7.5	7.0
III	6.0	6.0	6.5	6.5	6.0	6.0	6.0
IV	6.0	6.5	7.0	7.0	7.5	7.5	6.5
V	6.0	6.0	6.5	6.0	6.0	6.0	6.0
VI	6.0	6.0	7.5	7.8	6.8	7.5	6.8
VII	6.0	6.0	6.0	6.0	6.0	6.0	6.0
VIII	6.0	6.0	6.5	6.5	6.0	6.0	6.8
IX	6.2	6.2	7.5	7.5	7.5	7.5	7.0
X	6.4	6.4	7.5	7.5	6.5	6.5	7.5
XI	7.5	7.5	7.5	7.5	7.5	7.5	7.5
XII	6.0	6.0	7.5	7.5	7.5	7.5	7.0
XIII	6.5	6.5	7.5	7.5	7.5	7.5	7.3
XIV	6.0	6.2	7.5	7.5	7.5	7.5	7.2
XV	6.0	6.0	6.8	6.8	6.8	6.8	7.0
XVI	6.0	6.0	5.8	6.0	6.0	6.0	6.0
XVII	6.0	6.5	7.5	7.5	7.5	7.5	7.5
XVIII	5.5	5.5	6.0	6.0	6.0	6.0	6.0
XIX	6.8	6.8	7.5	7.5	7.5	7.5	7.5
XX	5.8	5.8	6.8	6.8	6.8	6.8	6.0
XXI	7.5	7.5	6.0	6.0	7.5	7.0	6.8
XXII	6.0	6.0	7.0	7.0	6.8	6.8	6.0
XXIII	5.8	5.8	6.0	6.0	6.0	6.0	6.5
XXIV	6.0	6.0	5.8	5.8	6.5	6.5	6.5
XXV	6.0	6.0	6.8	6.8	6.8	6.8	6.8

the cheeks do not collapse between the molar teeth. This is accounted for by the presence of a firm membrane intertwined with the buccinator muscle which produces folds in the mucous

Tables I, II, III and IV, show approximate pH determinations of human salivas. Red numbers indicate acid reaction; black numbers alkaline; and red encircled numbers, neutral.

membrane. In this way, it is prevented from penetrating between the occlusal surfaces of the teeth as they come together.

According to Maximow and Bloom (2), "all glands of the oral cavity independent of their size belong to the compound type",

TABLE II.

PATIENT	<i>l.p.</i>	<i>r.p.</i>	<i>l.s.x</i>	<i>r.s.x</i>	<i>l.s.l</i>	<i>r.s.l</i>	<i>s.p.</i>
XXVI	6.0	6.0	6.8	6.8	6.5	6.5	6.2
XXVII	6.0	6.0	7.5	7.5	7.5	7.5	7.5
XXVIII	6.0	6.0	5.8	5.8	6.5	5.8	6.5
XXIX	6.0	6.0	7.5	7.5	7.5	7.3	7.3
XXX	5.5	5.5	7.0	7.0	6.8	6.8	6.8
XXXI	5.8	5.8	7.5	7.5	7.0	7.0	6.5
XXXII	6.0	6.0	7.3	7.3	7.3	7.3	6.5
XXXIII	6.0	6.0	6.8	6.5	6.8	6.5	7.0
XXXIV	5.8	6.0	7.5	7.5	7.2	7.2	7.0
XXXV	7.5	7.5	7.5	7.5	7.5	7.5	7.5
XXXVI	7.5	7.2	7.5	7.5	7.0	7.0	7.0
XXXVII	5.5	5.5	7.3	7.3	7.3	7.3	5.5
XXXVIII	5.5	5.5	7.0	6.8	7.0	6.8	6.5
XXXIX	6.0	6.0	6.5	6.5	6.5	6.5	6.8
XL	5.5	5.5	7.2	7.2	6.5	6.5	7.0
XL I	6.0	5.8	7.3	7.3	6.8	6.8	6.5
XLII	6.0	6.0	7.0	7.0	7.0	7.0	7.2
XLIII	6.0	6.0	7.0	7.0	7.0	7.0	7.0
XLIV	5.5	6.0	5.5	5.5	5.5	6.0	7.0
XLV	5.8	5.8	7.3	7.3	6.5	7.3	6.8
XLVI	5.8	5.8	5.5	5.5	5.5	5.5	6.5
XLVII	6.0	6.0	6.0	6.0	6.8	6.0	6.8
XLVIII	6.0	6.0	6.8	6.8	6.5	6.5	6.0
XLIX	5.5	5.5	5.0	5.0	6.0	6.0	5.0
L	6.0	6.0	6.8	6.8	6.8	6.8	6.5

that is to say they consist of "several or many units or systems which are called lobules". The glands which open into the vestibule are the two parotids and the numerous small labial and buccal glands. The labial glands are situated in the mucous membrane of the upper and lower lips, and the buccal glands are a continuation of them in the mucous membrane of the cheeks. Certain writers

refer to molar glands, larger than the buccal, with ducts opening near the third molar teeth.

The ducts of the parotid glands, known as the ducts of Stenson, open into the vestibule on the buccal surface of the cheeks opposite

TABLE III.

PATIENT	left parotid	right parotid	left sub- max.	right sub- max.	left sub- lingual	right sub- lingual	Soft Palate
LI	5.8	5.8	7.0	7.3	7.3	7.0	5.5
LII	6.0	6.0	7.5	7.5	7.5	7.5	7.0
LIII	5.5	5.5	7.5	7.5	7.5	7.5	7.5
LIV	6.0	6.0	7.3	7.3	7.5	7.5	6.5
LV	6.5	6.4	7.2	7.2	7.2	7.2	5.5
LVI	6.8	7.0	7.0	7.3	7.0	7.3	7.3
LVII	5.8	5.8	7.0	7.0	6.8	6.8	7.0
LVIII	7.5	7.5	7.3	7.3	7.3	7.3	7.0
LIX	6.0	6.0	7.5	7.5	7.5	7.5	7.0
LX	6.0	6.0	6.8	7.0	7.0	7.0	6.0
LXI	6.0	6.0	6.8	6.8	6.8	6.8	6.8
LXII	6.0	6.0	7.5	7.5	7.5	7.5	6.5
LXIII	5.8	6.0	7.3	7.3	7.3	7.3	7.0
LXIV	6.0	6.3	6.0	6.0	6.0	6.8	7.0
LXV	6.0	6.0	7.0	7.0	7.0	7.0	7.0
LXVI	6.5	6.0	7.2	7.0	7.2	7.0	6.5
LXVII	6.0	6.0	7.2	7.0	7.0	7.2	6.5
LXVIII	5.8	5.8	6.0	6.0	6.0	6.0	6.0
LXIX	7.0	7.0	7.5	7.5	7.5	7.5	5.5
LXX	5.5	5.5	6.0	6.0	6.0	6.0	6.5
LXXI	6.0	6.0	7.0	7.0	7.0	7.0	6.5
LXXII	6.5	6.0	7.5	7.5	7.5	7.5	7.2
LXXIII	6.0	6.0	7.3	7.3	7.3	7.3	7.0
LXXIV	7.0	7.0	7.5	7.5	7.5	7.5	7.0
LXXV	5.8	6.0	7.0	7.3	7.3	7.3	7.0

the upper right and left second molar teeth. Here, a small papilla marks the outlet of each duct. This orifice is the narrowest part of the duct and just permits the entrance of a small probe. Each duct is about two and a half inches in length and commences at the anterior portion of the parotid gland. Passing over the masseter muscle to its anterior border, it curves inward almost at a right

angle. It then pierces the cushion of fat and the buccinator muscle, and continues obliquely forward beneath the mucous membrane to its opening.

The parotid is the largest of the salivary glands, and lying in

TABLE IV.

PATIENT	<i>l.p.</i>	<i>r.p.</i>	<i>l.s.x</i>	<i>r.s.x</i>	<i>l.s.l</i>	<i>r.s.l</i>	<i>s.p.</i>
LXXVI	5.8	6.0	7.0	7.0	7.0	7.0	6.5
LXXVII	6.0	6.0	6.5	6.0	6.5	6.0	6.8
LXXVIII	7.0	7.0	7.5	7.5	7.5	7.5	7.5
LXXIX	6.3	6.5	7.5	7.5	7.5	7.5	7.0
LXXX	6.0	6.0	6.0	6.0	6.0	6.0	6.0
LXXXI	6.0	6.0	7.0	7.0	5.8	5.8	7.3
LXXXII	7.5	6.5	7.0	7.0	7.0	7.0	6.5
LXXXIII	5.0	5.0	6.0	6.0	6.0	6.0	6.0
LXXXIV	7.5	7.5	7.5	7.5	7.5	7.5	7.5
LXXXV	6.2	6.2	7.0	7.0	7.0	7.2	7.0
LXXXVI	6.0	6.0	7.0	7.0	7.0	7.0	7.0
LXXXVII	6.0	6.0	7.2	7.2	7.2	7.2	6.8
LXXXVIII	6.0	6.0	6.0	6.0	6.0	6.0	6.5
LXXXIX	5.5	6.0	6.5	6.5	6.0	6.0	7.0
XC	5.8	5.8	7.3	7.3	7.3	7.3	6.5
XCI	6.0	6.5	7.0	7.0	7.3	7.3	7.0
XCII	6.0	6.0	6.0	6.0	6.0	6.0	7.0
XCIII	5.5	5.8	7.0	7.0	7.3	7.0	6.5
XCIV	6.0	6.0	6.0	6.0	6.0	6.0	6.0
XCV	6.5	6.0	6.0	6.0	6.0	6.0	6.3
XCVI	6.0	6.0	7.5	7.5	7.5	7.5	6.0
XCVII	7.5	7.0	7.5	7.5	7.5	7.5	6.8
XCVIII	6.8	6.8	6.8	6.8	6.8	6.8	6.0
XCIX	5.3	5.3	7.5	7.5	7.5	7.5	7.0
C	5.8	5.8	6.8	6.8	7.0	7.0	6.0

front of and below the ear, it occupies the ramus of the lower jaw. It is a pure serous or albuminous gland, that is to say the terminal or secretory portions of the glandular cavities contain only serous cells. The secretion is thin and watery as a rule, though occasionally it may be turbid. It lacks mucin but contains salts, proteins and ptyalin or salivary amylase. It varies little in the relative

amounts of its inorganic and organic constituents with the two classes of stimuli, viz. food and irritants, thus differing from the secretion of the submaxillary gland. Parotid saliva on account of its watery character is well adapted to the functions of cleansing the mouth and teeth, moistening and softening dry food, and dissolving many substances in order that they may stimulate the taste buds of the tongue. Through its ptyalin content, under favorable conditions, starch is converted, for the most part, into maltose. It is unlikely that this action occurs to any appreciable degree in the food bolus before it is swallowed but it is highly probable that under certain circumstances, considerable digestion of starch takes place in the stomach.

The labial and buccal glands belong to the mixed type, that is to say both mucous and serous cells are present in the terminal portions of the glandular cavities. In consequence, their secretion moistens the mucous membrane, and also lubricates it through its mucin content which tends to be mucilaginous and ropy.

REACTION OF PAROTID SALIVA

References to the reaction of fresh human saliva from the various salivary glands proper are not common in the literature. Such saliva usually has been obtained by inserting a fine cannula into the opening of the ducts. Observations have been made on human saliva collected from cases where, as a result of accidental injury, a fistula has been established. Normal salivary secretion in animals is sometimes studied by the creation of a fistula, the duct being diverted to the outside of the chin or cheek. The saliva is then easily collected and analysed.

According to Schafer (3), Raymond (4), Hammersten and Hedin(5), and Brubaker (6), human parotid saliva is alkaline in reaction. Schafer, and Hammersten and Hedin have stated that the first few drops secreted may be acid, and that the alkalinity of parotid saliva is less than that of the saliva from the submaxillary gland. This latter opinion has also been expressed by Raymond.

In a study of the reaction of salivas of patients seen in periodontal practice, the writer has made a series of approximate pH determinations in 100 different individuals, in each case using fresh saliva from the mouths of the ducts of the different salivary glands proper. The results are shown in Tables I, II, III, and IV. The

indicator known as Nitrazine and recently introduced by Squibb was employed. This new indicator is available both as a 0.1 per cent solution in dilute alcohol and in treated paper strips. The paper form was chosen because its wide range of color gradations, and corresponding pH determinations (pH 4.5 to pH 7.5) are particularly applicable to the study of salivary reactions. Acid, alkaline or neutral reaction of saliva can readily be ascertained. Further, this indicator allows the determination of pH of solutions within fairly narrow limits viz. two-tenths to three-tenths of one pH unit.

Nitrazine paper is available in strips 50mm. long and 7mm. wide. For the salivary tests, each strip was cut into small triangular pieces which are specially suitable for placing over the duct openings, on free surfaces like the soft palate and in gingival crevices and pockets. They are also particularly valuable under conditions where the amount of obtainable fluid is small. In the cases of determination of the reaction of parotid saliva, the cheek was first gently held away from the teeth, and the mouth of Stenson's duct and the mucous membrane for an inch or so around it carefully dried with cotton. Then, with the pliers, a small triangle of Nitrazine paper was placed over the mouth of the duct. When the paper had absorbed a sufficient quantity of saliva to saturate it throughout, it was immediately removed and placed on a white background, preferably glass, and examined for color value at the end of 60 seconds. This procedure is easily and rapidly carried out, and ensures against the loss of CO_2 in the saliva. A loss of CO_2 causes a rise in pH, and in certain methods of salivary collection and examination, it is a disturbing factor.

All the pH determinations in saliva were made on patients as they were presented in the ordinary routine of periodontal practice. And in all cases, the tests were carried out prior to all procedures of oral examination or treatment. Also, no preliminary mouth washing was permitted. It was impossible, of course, to eliminate such stimuli of the organs of special sense other than that of taste, in particular sight and smell, which are associated with the average dental office.

Saliva may be "resting" or "activated". According to Brawley, "the term 'resting saliva' is given to saliva without any form of induced stimulation." "Activated saliva" is saliva secreted by

induced stimulation, and is commonly understood to be more alkaline than "resting saliva". Marked activation of parotid saliva has been noted by the writer almost immediately following certain operative procedures. The problem arises as to the possible activation of parotid saliva as a result of the manipulation involved in the making of pH determinations as previously described. It seems reasonable that any stimulation produced thereby should be more pronounced in the right parotid saliva, in contrast to the left, as this saliva was always tested second in the order of pH determinations. More time is thus permitted for the induction of salivary flow from the right parotid gland from the first manipulation, and a second manipulation is involved as well. The results show that the average pH of the right parotid saliva is only .03 higher than the left. It would appear, therefore, that in these tests, the saliva dealt with is, in general, a "resting saliva."

THE ACID PAROTID

The findings of the writer in the reaction of parotid saliva under the conditions described previously are in marked disagreement with those of Schafer, Raymond, Hammersten and Hedin, and Brubaker. In the 200 different parotid salivas tested, 178, or 89 per cent, showed an acid reaction; 14, or 7 per cent, were alkaline; and 8, or 4 per cent, neutral.

THE ORAL CAVITY PROPER

When the teeth are closed in centric occlusion, the oral cavity proper is bounded anteriorly by the lingual surfaces of the crowns of the incisor and cuspid teeth, and laterally by the lingual surfaces of the crowns of the bicuspid and molar teeth, together with the associated gingivae and mucosa of the alveolar process. The roof is formed by the palate, the anterior part with its osseous base being known as the hard palate. The posterior or muscular portion is called the soft palate. The true floor is formed by the mylohyoid muscle and the base of the tongue. Posteriorly, the oral cavity proper extends to the so-called isthmus of the fauces.

According to Maximow and Bloom, the glands of the oral cavity proper are as follows:

"i. Glossomandibular glands opening at the bottom of the oral cavity between the tongue and the mandible.

1. Mandibular (submaxillary) gland—a large gland with a duct opening at the side of the frenulum of the tongue.
2. Sublingual glands, situated beneath the mucous membrane at the side of the frenulum of the tongue. Among them:
 - (a) The large sublingual gland with a duct opening into the duct of the mandibular gland.
 - (b) Several small glands varying in number and size. Their ducts open in many places along a fold of the mucous membrane, the *plica sublingualis*. At the posterior end of this group are the small glosso-palatine glands.
- ii. Glands of the tongue, lingual glands:
 1. Anterior lingual gland (gland of Blandin or Nuhn) situated at the side of the median line under the apex of the tongue.
 2. Posterior lingual glands:
 - (a) Albuminous or gustatory glands, glands of v. Ebner connected with the circumvallate papillae and opening into the circumvallate groove.
 - (b) Mucous glands of the root of the tongue.
 3. Glands of the palate, palatine glands."

Each submaxillary duct, or duct of Wharton, opens into the mouth through a soft eminence or papilla, the salivary caruncle, at the back end and side of the frenulum of the tongue. Each duct of the large sublingual gland, or duct of Bartholin, usually enters the mouth through the same orifice. Some authorities state that this duct occasionally opens upon the mucous membrane near the orifice of Wharton's duct. The small sublingual ducts, or ducts of Rivinus, are eight to twenty in number and open separately upon the surface of the mucous membrane over the ridge formed by these glands, the *plica sublingualis*.

The submaxillary gland of man is a serous and mixed gland, that is to say the majority of the terminal portions of the glandular cavities contain only serous cells, while the others are mucous with serous cells in the blind ends. The secretion is usually described as a clear, rather thin and somewhat viscid liquid which tends to froth easily. It contains mucin, salts and ptyalin. It should be pointed out, that depending upon the nature of the secretory stimulus, submaxillary saliva may be either thin and watery, through sparsity of mucin, or thick and viscid when rich in mucin.

Foods in general stimulate a secretion rich in mucin while irritants produce a profuse flow of watery saliva.

The sublingual glands are mixed glands with the mucous cells much greater in number than the serous cells. The serous cells have a marked muco-albuminous character. The secretion is ordinarily clear and mucilaginous and contains mucin, ptyalin and salts.

The mucin in submaxillary and sublingual saliva serves to lubricate the food preparatory to swallowing.

The glosso-palatine glands, the glands of the root of the tongue, and the palatine glands are all pure mucous glands. The posterior lingual glands connected with the circumvallate papillae as a rule contain only serous cells, while the anterior lingual glands contain mucous and muco-albuminous cells in the posterior portions, and muco-albuminous cells only in the anterior parts.

REACTION OF SUBMAXILLARY AND SUBLINGUAL SALIVAS

Schafer, Hammersten and Hedin, and Brubaker have stated that these salivas have an alkaline reaction, and are in general agreement that the sublingual saliva is more alkaline than the submaxillary secretion. The pH determinations of submaxillary and sublingual salivas, in the writer's cases, were carried out immediately following the parotid tests. A cotton roll was placed over the mouth of each Stenson's duct, and the floor of the mouth gently dried with cotton, with the tongue raised. Four triangles of Nitrazine paper were quickly placed in position with the pliers, one on each salivary caruncle, and one about half way back on each plica sublingualis. When each triangle of paper was saturated throughout, it was removed to the white glass background and examined for color value at the end of 60 seconds.

As was pointed out previously, the duct of Bartholin from the large sublingual gland usually enters Wharton's duct from the submaxillary gland and the mixed secretions of these glands then flow through a common orifice in the salivary caruncle. It is obvious therefore that pure submaxillary saliva is rarely if ever encountered in these tests. For tabulation purposes, however, the secretion flowing through the salivary caruncles is classed as submaxillary saliva, as undoubtedly it forms by far the larger proportion.

In the 200 submaxillary salivas tested by the writer, 89, or

44.5 per cent, showed an alkaline reaction; 74, or 37 per cent, were acid; and 37, or 18.5 per cent, neutral. In the 200 sublingual salivas tested, 87, or 43.5 per cent, showed an acid reaction; 82, or 41 per cent, were alkaline; and 31, or 15.5 per cent, neutral.

It will be of interest now to observe the grouping of reactions of the different salivas in the 100 individual patients. Three main groups will first be considered, viz.: (a) in which all the salivas, that is to say the secretions from the two parotid, two submaxillary, and sublingual glands, showed an acid reaction; (b) in which all the salivas were alkaline; and (c) representing the mixed types. The all acid group was 34 per cent; the all alkaline group only 4 per cent, and the group representing the mixed types, 62 per cent. In this latter group, the predominating class, with both parotid salivas acid in reaction, and both submaxillary and the sublingual salivas alkaline in reaction, the percentage was 26. The balance of the mixed types, in different combinations was 36 per cent.

THE REACTION OF HUMAN MIXED SALIVA

Mixed saliva is usually obtained by having the patient allow the saliva to collect naturally in the mouth and then expectorate it into a dish or tube; or by depressing the head, everting the lower lip, and allowing the saliva to drip into a container. In the obtaining of "resting saliva," no chewing or undue movements of the jaw are allowed for 30 minutes prior to the saliva collection.

While the majority of older text-books refer to mixed saliva as alkaline in reaction, a change is to be noted in the more recent works where it is stated to be neutral or slightly acid in reaction. The results of many recent investigations, notably those of Brawley (7), Starr (8), Bunzell (9) and Cassarato (10) have indicated that the average pH of normal resting saliva lies on the acid side of neutrality. Brawley found the average pH of normal resting saliva for 3405 cases to be 6.75.

Mixed saliva is usually understood to mean the saliva as found in the mouth, the product of all the salivary glands. In other words there is assumed to be a saliva common to the oral cavity as a whole which represents the mixed saliva collected in the test-tube and commonly used for testing and analysis. It is recognized that the salivary environment of the crowns of the teeth is one of the most important factors affecting their integrity. That the

crowns of all the teeth, apart from the mastication of food, chewing of gum and like conditions, are commonly found in an environment of thoroughly mixed saliva of all the glands seems highly improbable.

When the parotid saliva is acid in reaction at the duct openings, and the submaxillary saliva is correspondingly alkaline, an acid reaction usually prevails in the oral vestibule, with the exception of the lower labial region. Here, the influence of the submaxillary saliva is usually manifested with the production of neutral or alkaline reactions. The degree of the acid reaction in any other vestibular region may bear a relation to the proximity of the duct opening, but this is by no means a constant finding. Cases have been observed in which the degree of reaction in the upper labial region was the same as at the mouth of Stenson's duct, and others again, in the same region showed a less acid reaction. Whether this is due to loss of CO_2 , or mixing with alkaline secretions of the labial or buccal glands or saliva from the oral cavity proper, the writer is unable to state. Other cases have been noted in which the saliva in the upper labial region showed a more acid reaction than at the parotid duct opening. It is possible that here, acid secretions from the labial or buccal glands have played a part.

The reaction of the saliva in the oral cavity proper is dominated, in certain regions, particularly along the sides of and under the tongue by the secretions from the submaxillary and sublingual glands. When the teeth are normally present, it is improbable that any considerable mixing with the parotid salivas takes place in the resting state. Evidence of mixing of the salivas of the oral vestibule and the oral cavity proper, as indicated by reaction, is to be found on the surface of the tongue and soft palate. Numerous pH determinations of saliva on the upper anterior surface of the tongue were made and compared to those of the soft palate in the same cases. When related to the average pH of the six salivas tested, as some evidence of mixture, it was discovered that the pH of the saliva on the soft palate coincided with the average twice as often as the pH of the tongue. The tongue reactions were also more alkaline than this average in a much greater number. The soft palate reactions, however, were more acid in a greater number. The pH of the saliva on the soft palate also lay between the pH limits of the six salivas in each case, in a great many more instances

than the tongue. To some degree, therefore, it may be considered an index of general salivary mixture. A striking feature of the pH determinations made on the soft palate is the fact that the average pH of the 100 cases of the writer, herein described, almost coincides with the average finding of Brawley in his investigation of the pH of normal resting saliva in 3405 individuals. Brawley found an average of 6.75, and the writer an average of 6.69, with the almost negligible difference of .06.

The foregoing findings in general tend to confirm the standpoint that in the great majority of individuals, the surfaces of all the teeth are seldom subjected to a salivary pH environment representative of a thoroughly mixed saliva in each case. Analytic and pH findings of mixed saliva can not have the most intimate bearing on the etiology of the lesions that are initiated on the crown surfaces. Obviously parallel studies should be conducted in the physiological chemistry of the fluids of the vestibule and oral cavity proper in the same cases, and a search made for other related factors that distinguish one from the other.

The affirmation that labial and buccal cervical caries and erosion are pre-eminently lesions of the oral vestibule will be readily endorsed by all clinical observers.* It has been shown in this paper that parotid saliva is almost invariably acid in reaction in ordinary resting conditions. It may reasonably be deduced, therefore, that acid parotid saliva has some etiological relationship with these lesions of the vestibule.

APPENDIX

The dental lesion known as erosion is commonly evidenced by the development of superficial circumscribed excavations which are smooth and highly polished and localized on the exposed surfaces of the teeth. A class of erosion which uniformly involves all the hard surfaces is known but is encountered infrequently. Erosions from extraneous acids, e.g. acid vapors, eating of grape fruit, and lemon and grape sucking have also been described. The ordinary class of erosion, the chemico-mechanical variety, which is commonly seen in dental practice, rarely affects the lingual surfaces of the teeth. It shows a characteristic predilection for the labial and buccal surfaces, the upper teeth being more frequently involved

*This is supported in the Appendix.

than the lowers. The lesion, as a rule, does not tend to encircle the tooth, nor to extend under the gingival margin. From the foregoing it is plain that erosion is conspicuously a lesion of the oral vestibule.

It is quite reasonable to suppose that the acid secretions in the vestibule produce a superficial decalcification of the hard surfaces which is removed by brushing with abrasive dentrifices.

Dental caries always begins on the surface of the clinical crown and never in the interior of the tooth. The general regions on tooth surfaces where caries is initiated are three in number, viz.: in pits and fissures; on proximal surfaces under the contact point; and on labial and buccal surfaces near the gingival line. Labial and buccal cervical caries, as in the case of erosion, does not tend, as a rule, to extend beneath the gingival margin, and rarely finds its inception in this region. Clinical observation plainly teaches that the lingual surfaces of the teeth, with the exception of pits and fissures in the upper central and lateral teeth, are seldom attacked. Cervical caries is therefore, also in the main, a lesion of the vestibule.

In a study of caries, the clinical picture must constantly be kept in mind. As pointed out previously, cervical caries does not tend to spread under the gingival margin, and seldom, if ever, begins in the gingival crevice. The fluid of the crevice, with few exceptions, is alkaline in reaction. This has been proven in hundreds of tests made by the writer. Evidently this alkaline reaction, in some manner, inhibits the colonization of acid-forming bacteria on the crevicular tooth surface and thus prevents the initiation of caries.

It is also commonly observed that the lower anterior teeth, in a great many mouths exhibit a marked immunity to caries, cervical and proximal. It has been shown previously that very frequently the lower anterior region is under the dominance of alkaline sub-maxillary saliva, not only lingually but also labially. As a rule, the immunity of these teeth to caries has been ascribed to the cleansing action of lips, tongue and food, and the motion of saliva. Undoubtedly these factors may play a part in cleansing, but the inability of the tongue to play an effective role is only too frequently seen in the production of supragingival calculus. The value of the tongue and lips in cleansing the proximal surfaces of the teeth is extremely small. The gingival crevices are frequently

filthy and yet caries does not begin in these zones. It seems reasonable to believe, therefore, that in the case of the lower anterior teeth, the alkaline environment peculiar to this region in many mouths prevents, in some way, the colonization of acid-forming bacteria on the tooth surfaces, as in the gingival crevices.

In labial and buccal caries, the susceptible areas on the teeth are clearly those which are least subjected to cleansing processes, viz.: the cervical portions. It must be pointed out, however, that the continued presence of adherent food debris and bacterial plaques by no means ensures the initiation of caries in these regions. The presence of acid-forming bacteria under suitable cultural conditions, and carbohydrate debris that remains in contact with them for sufficient time to form acid are prerequisite for the beginning of caries.

Among these acid-forming bacteria, *B. acidophilus* is recognized as the most important. Protected by films and food accumulation, it is able to elaborate acid of sufficient intensity to thoroughly decalcify enamel. It also colonizes readily in culture media sufficiently acid, e.g. pH 5.0, to inhibit non-acid-resisting organisms like streptococci. It seems obvious that their germination would be facilitated in pasty starch debris moistened by acid saliva, a condition which must be encountered much more frequently in the oral vestibule than in the oral cavity proper.

It has been shown that predominately carbohydrate diets increase the number of acid-forming organisms in the mouth. It would be of importance, under such dietetic conditions, to determine by some quantitative method of estimation whether *B. acidophilus* is greater in number in tooth-scrapings from the oral vestibules which show an acid salivary reaction than in the oral cavities proper with saliva alkaline in reaction, in the same mouths. The general influence of acid salivary reaction on the establishment of favorable cultural conditions for *B. acidophilus*, in the etiological syndrome of cervical caries, would then be confirmed.

BIBLIOGRAPHY

- (1) PREISWERK: *Atlas and Text-Book of Dentistry*, W. B. Saunders Company, 1906.
- (2) MAXIMOW AND BLOOM: *Text-Book of Histology*, W. B. Saunders Company, 1931.
- (3) SCHAFER: *Text-Book of Physiology*, Vol. I, Young and Pentland, 1898.

- (4) RAYMOND: *Human Physiology*, W. B. Saunders Company, 1905.
- (5) HAMMERSTEN AND HEDIN: *A Text-Book of Physiological Chemistry*, John Wiley & Sons, Inc., 1915.
- (6) BRUBAKER: *A Text-Book of Human Physiology*, P. Blakeston's Son & Co., 1919.
- (7) BRAWLEY: Studies of the pH of Normal Resting Saliva, *Journal of Dental Research*, February, 1935.
- (8) STARR: *Jour. Biol. Chem.* 54, 43, 1922.
- (9) BUNZELL: *Colgate Bull.* No. 1, 2, 3, 4, 1922.
- (10) CASARATTO: *La Stomatologia*, 25, 461, 1927.

PART II

A LIQUEFYING AMYLASE IN HUMAN SALIVA, AMYLOPECTIN, AND DENTAL CARIES

CARIES IN PREHISTORIC MAN

A study of the skeletal remains of Neanderthal man shows that he had not been afflicted with dental caries (1). Neanderthal man brought the Mousterian culture into Europe, and which was first recognized in French caves. The Middle Palaeolithic period was occupied solely by the Mousterian culture, and according to archaeologists, probably about 200,000 years ago.

The fossil remains of Rhodesian man, (one specimen) discovered in the Broken Hill mine, Northern Rhodesia, in 1921, showed teeth ravaged by caries (2). It is thought that Rhodesian man was probably alive in Africa when Neanderthal man dominated Europe. This shows that caries affected the teeth of man in very early times.

Neolithic man also suffered from dental caries. In 1870, Mummery (3) in an extensive survey of the teeth in a large number of skulls, 1658 of which were tabulated, found caries in 2 of 68 skulls from long barrows in Wiltshire, and 24 in 60 skulls from long barrows in Yorkshire. The makers of long barrows belonged to the Mediterranean people (4), who preceded the Beaker folk in England. The skulls are principally long-headed and it is most probable that they were buried in Neolithic times.

CARIES IN THE ROMANS IN ENGLAND, ANGLO-SAXONS AND THE EGYPTIANS

Colyer (5) has pointed out that Roman skulls found in England show abundant evidence of caries. Forty-one cases of caries were found in 143 skulls.

Out of 76 skulls belonging to the Anglo-Saxon period, caries was found in 12, according to Colyer.

In 36 cases of Egyptian mummies examined, 15 showed dental caries. In 104 Egyptian skulls examined by Turner, 40.38 per

cent exhibited caries. These skulls belonged to the period of the twenty-fifth to the thirtieth dynasties.

It would appear that with the development of high standards of civilization the prevalence of dental caries tended to increase. According to Barber (6), there seems to be no doubt that the exploitation of barley and wheat created the earliest civilizations in Mesopotamia and Egypt. Cultivation of these plants provided a certain and highly yielding food, and the nomadic way of living tended to be replaced by one of greater leisure.

CARIES IN EXISTING PRIMITIVE PEOPLES

Caries was reported by Mummery in his examination of the skulls of Eskimos (1 case in 69 skulls); American Indians of the Northwest Coast (2 in 51); American Indians of the Interior, (2 in 21); Fiji Islanders (2 in 38); Maori, (2 in 66); Eastern Polynesians, (8 in 79); Sandwich Islanders (4 in 21); Australian Primitives, (27 in 132); Tasmanians, (9 in 33); Zulu Kaffirs, (6 in 49); African tribes supplying the slave markets, (66 in 268); The Bushmen (6 in 29); Natives of Southern India, (10 in 71); Natives of Northern India, (9 in 152); Malays, (3 in 24) and Chinese (6 in 27).

It will be noted that the lowest per centage of skulls showing caries was found in the Eskimos. Valuable data relating to the problem of caries in the Eskimos have been obtained from expeditions to Alaska under the leadership of Dr. L. M. Waugh, Dental Director of the United States Public Health Service. Rosebury (7) reports that in Kipruk, a primitive native village without resident trader, the average of carious teeth in 9 Eskimos examined was 1.2 per cent. The diet was largely fish, meat, fat, roots, greens, berries in summer, tea without sugar and no milk. At Eek, an isolated village with resident trader, the average of carious teeth was 18.1 per cent, in 20 Eskimos examined. The diet included flour in abundance, sugar, pilot bread, some candy and little milk. At Moravian orphanage where the diet was supervised, the average of carious teeth was 10 per cent. Eighteen full-native inmates were examined. The diet was a composite of native and white, and included butter and commercial fat, fresh and canned vegetables and fruit, canned milk, cereals, flour chiefly for bread, and sugar. The diet included more candy and less pilot bread.

Rosebury (8) examined the clinical data in the light of experimental findings in rat caries, where the primary causative agencies were found to be hard, compact, carbohydrate-rich foods. He concluded that pilot bread or ship's biscuit, and certain kinds of candy, on this basis, were the only foods in the culpable class. It was significant that the consumption of pilot bread showed a quantitative correlation with the incidence of caries in the Eskimos examined at Eek, Orphanage and Kipruk. It is also of interest to note that Rosebury suggests that the native Eskimo diet is "inactive" rather than "protective" and in the Eskimo's association with the white man's diet, he is subjected to "active primary" causes of dental caries. The writer believes that the native Eskimo diet, while it may be "inactive", nevertheless may easily be "protective".

The suggestion that a protective agent against caries is present in certain foods has been brought forward by Osborn and Noriskin (9) of Johannesburg. In a recent work, they endeavoured to ascertain why civilization gives rise to dental caries in the Bantu. They were able to confirm an earlier conclusion that the incidence of caries is greater in nations who have adopted the European diet. The South African Bantu on a native diet, which is high in cereals, develops caries to a minor degree. With civilization, which includes an increased consumption of European foods, the incidence of caries is greatly increased. In an extensive survey of Bantu natives who had worked neither in towns or the mines previously, an attempt was made to correlate the incidence of caries with individual items of the diet. Among native foods, the consumption of fresh milk, Kaffir corn, potatoes and sweet potatoes is shown to have a relation with an increased percentage of caries. When European foods are consumed, mainly machine ground mealie meal, European bread, sugar, sweets, jam, tea and coffee, the percentage of carious mouths is shown to be greatly increased. From an analysis of their findings, Osborn and Noriskin conclude that one or more of these three factors probably cause the increase in caries, viz: (a) European bread, (b) machine ground mealie meal, and (c) foods containing sugar. Based on observation, these investigators argue that sugar as it occurs in nature, e.g. in sugarcane, is not a major cause. In conclusion, these authors suggest that in the natural or crude state, the carbohydrate is accompanied

by some protective agent, which is removed in the processes of refinement. That is to say, they suggest that in the natural or crude state, the carbohydrates of sugar-cane or wheat are accompanied by a "protective" agent, which is lost in the making of refined sugar and refined wheat flour, both of which may cause dental caries.

STARCH: AMYLOSE AND AMYLOPECTIN

Starch is a member of that most complex group of carbohydrates known as polysaccharides, the chemical constitution of which has presented a problem of the greatest difficulty. Recently, through the investigations in Birmingham, of Haworth, Hirst and their collaborators, a definite concept of the structure of the starch molecule has been achieved. And as Hanes (10) has pointed out, "According to the view which has now gained wide acceptance, the starch molecule is regarded as consisting of a chain structure made up of α -glucose units joined together by glucosidic linkages."

It has long been known that the intact starch granule comprises an envelope or external membrane and the bulk of the starch substance contained therein. Starch can be separated into two fractions differing greatly in their physical properties. These two fractions have been termed alpha-amylose and beta-amylose by Meyer, and amylose and amylopectin by Maquenne and Roux. Amylose is readily soluble in water, while amylopectin is dissolved with difficulty. According to Hammersten and Hedin (11), amylopectin is a slime-like substance and is insoluble in boiling water and dilute alkalies.

The natural starch granules are insoluble in cold water but when an aqueous suspension of starch granules is heated, they swell to a great size and are seen under the microscope as thin sacs enclosing the hydrated starch bulk. On rupture, starch paste is formed. According to Maquenne the amylopectin is solely responsible for the formation of the paste. The paste in other words is composed of dissolved amylose which is thickened by the amylopectin colloiddally dispersed. Maquenne and his students have described the envelope material of the starch granule as "amylopectin" and the contents as "amylose." It has been pointed out by Hanes that these terms have been used in different senses by different authors, and that the products so designated

are not identical. And according to the methods of separation used by different workers, the proportion of the two fractions, amylose and amylopectin varies greatly.

According to Samec's investigations, amylopectin differs from amylose in relation to its phosphorus content. Whereas amylopectin represents a phosphoric-acid-ester of the starch, with an average phosphorus pentoxide content of 0.175 per cent, amylose is phosphorus-free. The phosphorus content was regarded as the main factor in the production of viscosity in starch paste.

The investigations of Hirst (12) and his co-workers, in 1932, failed to substantiate these views. It was found that while amylose and amylopectin in the free state differed markedly in their physical properties, mainly solubility and viscosity in solution, no chemical difference existed between them. Employing the freezing out method of Ling and Nanji in the separation of amylose and amylopectin, it was found that both of these fractions retained the original phosphorus content of the starch. It was concluded that the differences in the solubility and viscosity manifested by amylose and amylopectin were due to differences in the state of aggregation of their chemical units.

It has been pointed out by Hanes, that the evidence along several lines would indicate that the material forming the envelope of the starch granule and the bulk of the starch substance differ in physical properties. Satisfactory evidence as to whether or not they differ chemically appears to be lacking at the present time. Sande-Bakhuyzen (13) regards the envelope material as a less hydrated form of the starch constituting the bulk substance.

The envelope material which appears as thin sacs either in starch paste prepared by heating an aqueous suspension of starch grains, or in a suspension in cold water of air-dry starch previously rubbed in a mortar, is dissolved by saliva. The process is one of enzyme liquefaction and is readily observable in the microscope. This phenomenon has been employed by the writer in a test as a criterion of the activity of salivary liquefying amylase.

Through the action of enzymes, termed amylases, and their activators, under favorable conditions, the amylose and amylopectin fractions of starch are converted into maltose with dextrins formed as intermediate products. Maltose in common with other disaccharides is considered to be a glucoside derived from the conden-

sation of two monosaccharide units with the elimination of a molecule of water between them. On hydrolysis, maltose yields two molecules of glucose. This is accomplished through the action of the enzyme maltase.

In starch degradation as a result of the action of most amylases, according to Hanes, there occurs (1) an initial rapid decrease in viscosity; (2) the conversion of the substrate into products exhibiting altered iodine coloration; and (3) the appearance of reducing products. This investigator has stated: "The changes in these three properties have formed, respectively, the criteria of the so-called liquefying, dextrinogenic and saccharogenic activities of amylases."

THE LIQUEFYING AMYLASE (AMYLOPHOSPHATASE)

In 1878, Märcker (14) observed that malt amylase must be a mixture of two components, viz, a liquefying and a maltose-forming fraction (Tauber). Haldane (15) in 1930 pointed out that in starch degradation the liquefying component did not appear to be identical with the sugar-producing amylase, as it differed from it in its heat stability and otherwise. Pringsheim (16) in 1932 stated that the liquefaction of starch paste is undoubtedly due to the presence of a particular amylophosphatase. The separation of this component from ungerminated barley was finally reported in 1935 by Waldschmidt-Leitz and Mayer (17) who also applied to this enzyme the term amylophosphatase. These investigators emphasized the capacity of this enzyme to liberate esterified phosphorus and showed that with starch paste it also caused a considerable fall in its viscosity with a small increase in reducing power.

The recent findings in the field of amylase investigations show that malt amylase consists of a mixture of three separate enzymes. Besides the forementioned liquefying amylase, it has been demonstrated that saccharogenic and dextrinogenic amylases are present as well. Observations based on experiments carried out with the differential diffusion technique of Wijsman showed conclusively the existence of saccharogenic and dextrinogenic components in the amylase system of malt.

CARBOHYDRATE DEBRIS AND DENTAL PLAQUES

Hadley (18) showed by her quantitative method of estimating *B. acidophilus* in saliva that in caries-susceptible cases, the examina-

tions were 100 per cent positive. In the caries-free group only 42 per cent were positive, but the average count was very low as compared to the susceptible cases, 600 as against 60,000. In the caries-free cases many more positive cultures were obtained from saliva than from tooth-scrappings. It is obvious from these findings that the localization of the organisms on the tooth-surfaces has been hampered in some manner, and that agencies that facilitate localization favor the initiation of caries. The retention of carbohydrate debris under certain conditions would seem to belong in this category.

Blayney, Kesel and Wach (19) prepared many ground sections of teeth showing bacterial plaques on the enamel surface. The enamel beneath some plaques was carious, while beneath others it was normal. In a study of the morphology of organisms found in plaques by direct smear preparations, these investigators found that carious plaques were always positive for *B. acidophilus*, while non-carious plaques were negative. The smears were made after the removal of all superficial debris.

It seems logical, therefore, to deduce that plaques having the capacity of initiating caries differ from non-carious plaques in some fundamental manner. They must contain material inherently able to form sugar. They must of necessity remain in contact with the enamel surface for sufficient time to allow the bacteria to form acid, and to permit, by protection from the saliva, its formation with sufficient intensity to thoroughly decalcify the underlying enamel.

It is known that starch in solution exists as aggregates or micelles formed by the association of varying numbers of its simple macromolecules. The less soluble fraction, amylopectin, is thought to be in a highly aggregated state while the readily soluble fraction, amylose, exists in a form in which the macromolecules are more dispersed. On this basis, the differences in viscosity and solubility of these fractions are explained.

Amylopectin, therefore, under certain conditions, would seem to adequately furnish the qualifications, previously mentioned, for the establishment of caries-forming plaques. Its sticky and resistant nature, its capacity for sugar production, and its presence in boiled and baked starchy foods would seem to give it a place of first importance in the problem of carbohydrate debris in the human mouth.

The hulls of the starch grains, although constituting a small proportion of the total starch substance, may also play a prominent role in the caries picture. They yield in the cooking of starches and under oral conditions a gelatinous substance which forms a tenacious binding material. This, together with its probable capacity for sugar-formation, would make its retention on the tooth-surface, through failure of enzymatic action or otherwise, an important factor in the local etiologic syndrome of caries on smooth surfaces.

HUMAN SALIVARY ENZYMES

According to various authors and investigators, human saliva has been shown to contain the following enzymes: ptyalin or salivary amylase, maltase, phosphatase, catalase, oxidases, tributyrinase, as well as dipeptide and tripeptide splitting enzymes.

Ptyalin is commonly understood to be a salivary enzyme capable of splitting starch and converting it into the sugar maltose. Berzelius (20) gave the name "ptyalin" to this amylolytic substance in 1840. More recently the term "salivary amylase" has tended to replace the older term.

The dextrinogenic amylase of malt induces the initial phase of starch degradation with dextrins as the predominating products, and destruction of the iodine coloring property. This is in contrast to the saccharogenic malt amylase which produces maltose rapidly at first without destroying the iodine coloring property. On completion of its action, a blue-violet or violet iodine coloration remains owing to the presence of a residual dextrin.

Ptyalin and pancreatic amylase are described as amylases of the dextrinogenic type. The action of these enzymes of animal origin is closely similar but their degradation processes are not identical. It is probable however that after prolonged action the principal product formed is maltose, but as Hanes has pointed out, it must not be assumed that this is the exclusive reducing product.

The possibility of the presence of a saccharogenic component in ptyalin associated with the dextrinogenic enzyme suggests itself but up to the present time there is no conclusive evidence of the coexistence of these distinct amylase enzymes in saliva. The problem is now under investigation in our laboratory.

It has been demonstrated by Pottevin and Ohlsson that by briefly heating amylase solutions, it is possible to completely destroy the saccharifying components and still retain the liquefying action. Holmberg further showed, in comparative experiments, that with liver amylase, iodides inhibit sugar-formation while the liquefaction process is activated.

Using malt extract diluted with distilled water and heated in a water bath for 10 minutes at 70° C., it was found in our laboratory that both the liquefying and dextrinogenic enzymes were still active with the tests employed. The hulls in starch paste were observed in the microscope to liquefy quickly, and with iodine the starch paste passed from the blue coloration, through violet to an almost colorless stage.

When a drop of human saliva is added to a small amount of starch paste, there is to be observed in the microscope, as a rule, a fairly rapid liquefaction of the hulls of the starch grains present in the paste. This phenomenon was first seen by the writer in September, 1937. When iodine is added to the mixture, the color changes usually take place which denote the presence of a dextrinogenic enzyme, viz., from blue through violet to the colorless or almost colorless stage.

When human saliva, diluted and undiluted, was heated in a water bath for 10 minutes at 70° C., and subjected to the same tests with starch paste, it was found that no liquefaction of hulls took place, and that there was no disappearance of the products which give a blue color with iodine. This was taken to indicate that both the liquefying and dextrinogenic enzymes were inactivated.

When the experiments were repeated with diluted and undiluted saliva heated to 65° C. for 10 minutes, both the liquefying and dextrinogenic enzymes were found to be active. When pure saliva was heated to 75° C. for 1 minute, with the starch paste at 37° C. liquefaction of the hulls took place fairly rapidly but no transformation from the blue color developed with iodine.

When pure saliva was heated to 72° C. for a few seconds rapid liquefaction of the hulls took place at 37° C. and with iodine the blue coloration was destroyed. When the same saliva was reheated to 75° C. for a few seconds, with the starch paste at 37° C., fairly rapid liquefaction of the hulls took place but no action of a dex-

trigenous enzyme was to be observed with the iodine test. From these experiments it was concluded that a distinct liquefying amylase in human saliva was demonstrated.

POSSIBLE RELATIONSHIP OF THE LIQUEFYING AMYLASE OF SALIVA TO DENTAL CARIES

It would seem reasonable that in individuals poor in salivary liquefying amylase, from whatever cause, the retention of carbohydrate debris, mainly amylopectin and starch hulls, on tooth-surfaces not readily cleansed mechanically, would be facilitated. Under favourable conditions and in locations where the removal of this debris is greatly delayed through slowness of liquefying action or other causes, it seems obvious that colonization of acid-forming bacteria would readily occur. With the production of acid on the tooth-surface, and protected from the saliva, caries of enamel is initiated.

It seemed possible that a decrease in activity of the liquefying amylase in human saliva might play a significant role in the production of caries on smooth surfaces. It was decided, therefore, to determine if any relationship existed between the liquefying activity of saliva and susceptibility to caries in the same individual, such susceptibility being evidenced by the presence of active caries.

After some experiments designed to arrive at a suitable test to show more clearly the relative activities of the liquefying action of salivas, it was decided to take one part of saliva diluted with 24 parts of fresh distilled water, and add one drop of this mixture to two drops of standard starch paste. The rate of liquefaction of the starch hulls, is then observed in the microscope.

In our first test of the saliva of children, two boys, both 13 years of age, one practically immune to caries, and one fairly susceptible were examined. It was found that the saliva of the immune boy completely liquefied the starch hulls in 30 seconds, while the saliva of the susceptible boy took 11 minutes for full liquefaction.

Later the saliva of a young man, age 21, was examined. The teeth were all present and free from fillings. There was no evidence of caries at the time of examination of the saliva. Using the test previously described, full liquefaction of the hulls took place in one minute. Then the saliva of a young woman, age 19, was

examined. Twelve carious cavities had developed in the previous 12 months and at the time of salivary examination 11 cavities (5 cervical and 6 proximal) were present. It took over 5 minutes to liquefy the starch hulls.

The saliva from a number of individuals susceptible to caries has since been examined and the marked decrease in liquefying activity usually manifested suggests that this factor plays an important part in the initiation of dental caries. Obviously this procedure, should be carried out on a large number of people, and at different times on the same individuals to prove the validity of a relationship of impaired activity of this liquefying enzyme to caries. Nevertheless from the findings available, there is a suggestion of a new approach in the study of this important problem.

CERTAIN LABORATORY FINDINGS

The following findings made in our laboratory are of interest and appear to have a bearing on the problem in general.

(a) Liquefaction of the hulls in starch paste was observed in the microscope with infusions of bran, whole wheat flour, whole wheat bread and tobacco. Potato juice especially near the skin, and the juice of onions and apples also had a liquefying action. This action on the part of infusion of whole wheat bread was very slow and it was noted that white flour and white bread infusions had no liquefying action. Samec and Knez (21) found that a variety of extracts including that of bone attack amylopectin and as this action is ascribed to the presence of phosphatases it is probable that our findings are to be explained on the same basis. It is probable also that the protective agent mentioned by Osborn and Noriskin of Johannesburg is a liquefying enzyme and belonging to the phosphatase group. In passing it might be pointed out that the reputed partial immunity of tobacco-chewers and cigar-smokers may be explained as resulting from the introduction of this enzyme into the saliva.

(b) It has also been demonstrated that solutions of phosphate buffers ranging from pH 5.0 to pH 6.5 brought about liquefaction of the starch hulls in a relatively short time and in direct ratio to the acid reaction of the solution. At pH 7.0 and above, no observable liquefaction took place.

(c) It was found that when the starch paste was rendered alkaline the action of the liquefying enzyme was greatly retarded.

(d) It was observed that the addition of small quantities of surface tension reducents, such as sodium oleate, to the starch paste greatly retarded the liquefying process. This probably was due to the adsorption of such agents on the surfaces of the hulls.

(e) It was demonstrated that with teeth suspended in buffered solution of pH 5.0 to which a small amount of sodium oleate was added the enamel surface was not attacked. In the absence of the sodium oleate marked decalcification was noted in 24 hours.

(f) It is known that intact starch grains are insoluble in cold water. With boiled starches where an abundance of water is present the starch hulls are swollen and heavily hydrated. This is not true however for baked starches as found in bread, cake, etc., in which the amount of water used in making the dough is sparse and the heating, in consequence, does not swell the hulls. This has an important bearing on the rate of liquefaction of the baked hulls. With macerated bread in a buffered solution of pH 6.0 the hulls of the starch grains showed a marked amount of liquefaction. With the addition of a small amount of active saliva to buffered solutions of macerated bread at pH 5.0 and 6.0 the hulls were almost completely liquefied in a much shorter time.

GENERAL CONCLUSIONS, AND THE RELATIONSHIP OF THE FINDINGS TO CARIES IN THE ORAL VESTIBULE

The following conditions would seem to play a part in the establishment of an environment conducive to the initiation of dental caries:

1. The presence of amylopectin and starch hulls on the tooth surface.
2. Saliva poor in liquefying amylase.
3. A reduced volume of saliva and therefore reduced conditions for hydration and solution as well as impaired enzymatic breakdown of the starchy debris.
4. Fairly acid reaction of saliva with poor liquefying activity in the case of both boiled and baked starchy foods.

5. The presence on the starchy debris of adsorbed materials such as soap in dentifrices which prevent in some degree the action of the liquefying enzyme. It is possible that mucin may act as a covering and thus protect the debris from the action of the enzyme.

In the foregoing paper (22) by the writer, it was pointed out that human parotid saliva is almost invariably acid under ordinary resting conditions, and that labial and buccal cervical caries are pre-eminently lesions of the oral vestibule. It was further stated that it is a common observation that the lower anterior teeth in a great many mouths exhibit a marked immunity to caries, both cervical and proximal. And it was shown that the lower anterior region of the vestibule is very frequently under the dominance of alkaline mandibular saliva.

The conclusion was reached that it seemed reasonable that acid parotid saliva had some etiological relationship with cervical caries in the vestibule. In the first place it seems obvious that germination of acid-forming bacteria would be facilitated in starchy debris moistened by saliva acid in reaction. Further, it has been pointed out that the reaction of the starchy medium has a bearing on the liquefaction of the hulls. An alkaline reaction inhibits liquefaction while an acid reaction favors it. This is found to be the case either in the presence or absence of the liquefying enzyme. The rate of liquefaction of starchy debris on the tooth surface when moistened by an acid saliva rich in liquefying enzyme would be greatly accelerated. This naturally tends to cleanse the tooth surface. However, when the liquefying enzyme is deficient in amount, with an acid reaction prevailing, the liquefying process while operative is greatly retarded. Thus the retention of the debris on the tooth surface is favored. The presence of the gelatinous hull substance and incorporated amylopectin under these conditions furnishes an ideal environment for the colonization of acid-forming bacteria and the localization of acid production on the enamel.

In the foregoing an interrelationship between the activity of a salivary liquefying amylase and certain environmental conditions commonly found in the oral vestibule has been described. The operation of several factors in this interrelationship would seem to satisfactorily explain the marked susceptibility to dental caries so frequently observed on certain tooth surfaces in the oral vestibule.

BIBLIOGRAPHY

- (1) MACNEVIN AND VAUGHAN: *Mouth Infections*, Vol. I, Issued by the Joseph Purcell Research Memorial, New York, 1930.
- (2) KEITH: Evolution of Man, *Encyclopaedia Britannica*, Vol. XIV, 14th edition, 1932.
- (3) MUMMERY: *Trans. Odonto. Soc.*, Vol. ii, NS., 1870.
- (4) CRAWFORD: Barrow, *Enc. Britannica*, Vol. V, 14th edition, 1932.
- (5) COLYER: *Dental Surgery and Pathology*, 5th edition, Longmans, Green and Co., 1923.
- (6) BARBER: Cereals, *Enc. Britannica*, Vol. V, 14th edition, 1932.
- (7) ROSEBURY: Dietary Habits of Kuskokwim Eskimos, with varying Degrees of Dental Caries, *Journal of Dental Research*, Aug., 1937.
- (8) ROSEBURY: Interpretation of Recent and Experimental Data on Etiology of Dental Caries, *Journal of Dental Research*, Oct., 1937.
- (9) OSBORN AND NORISKIN: The Relation between Diet and Caries in the South African Bantu, *Journal of Dental Research*, Oct., 1937.
- (10) HANES: The Action of Amylases in Relation to the Structure of Starch and its Metabolism in the Plant, *The New Phytologist*, April, 1937.
- (11) HAMMERSTEN AND HEDIN: *A Text-Book of Physiological Chemistry*, John Wiley and Sons, Inc., 1915.
- (12) HIRST: Hirst, Plant and Wilkinson: *J. Chem. Soc.*, 1932.
- (13) SANDE-BAKHUYZEN: *Proc. Soc. Exp. Biol.*, N.Y., 1925.
- (14) MÄRCKER: *Chem. Zentr.*, 1878.
- (15) HALDANE: *Enzymes*, Longmans, Green and Co., 1930.
- (16) PRINGSHEIM: *The Chemistry of the Monosaccharides and of the Polysaccharides*, McGraw-Hill Book Company, Inc., 1932.
- (17) WALDSCHMIDT-LEITZ AND MAYER: *Hoppe-Seyl. Z.*, 1935.
- (18) HADLEY: A Quantitative Method for Estimating Bacillus Acidophilus in Saliva, *The Journal of Dental Research*, Oct., 1933.
- (19) BLAYNEY, KESEL AND WACH: Dental Caries 1: New Method of Studying Bacterial Plaque, *Journal of Dental Research*, Sept., 1936.
- (20) BERZELIUS: *Lehrbuch der Chemie*, ix, 217, 1840.
- (21) SAMEC AND KNEZ: Sur l'hydrolyse enzymatique des amylophosphates naturels et synthétiques, *C.R. Ac. Sc.*, 181-532, 1925.
- (22) BOX: Human Salivary Reactions in the Oral Vestibule and Oral Cavity Proper, *Oral Health*, Sept., 1937.

NECROTIC GINGIVITIS

Its Histopathology and Treatment
with an Adherent Dressing

By

HAROLD K. BOX, D.D.S., Ph.D.

Department of Periodontology,

Faculty of Dentistry

University of Toronto

and

ARTHUR W. HAM, M.B.

Department of Anatomy,

Faculty of Medicine

University of Toronto

Reprinted by permission of ORAL
HEALTH, (Canada) from December,
1942 issue.

BULLETIN NUMBER TWENTY-FIVE

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

January, 1943

NECROTIC GINGIVITIS

Its Histopathology and Treatment
with an Adherent Dressing

By

HAROLD K. BOX, D.D.S., Ph D.
Department of Periodontology,
Faculty of Dentistry
University of Toronto

and

ARTHUR W. HAM, M.B.
Department of Anatomy,
Faculty of Medicine
University of Toronto

Reprinted by permission of ORAL
HEALTH, (Canada) from December,
1942 issue.

BULLETIN NUMBER TWENTY-FIVE

ISSUED BY

THE CANADIAN DENTAL RESEARCH FOUNDATION

January, 1943

PRINTED IN CANADA

NECROTIC GINGIVITIS

Its Histopathology and Treatment with an Adherent Dressing

HAROLD K. BOX

*Department of Periodontology, Faculty of Dentistry
University of Toronto*

and

ARTHUR W. HAM

*Department of Anatomy, Faculty of Medicine,
University of Toronto.*

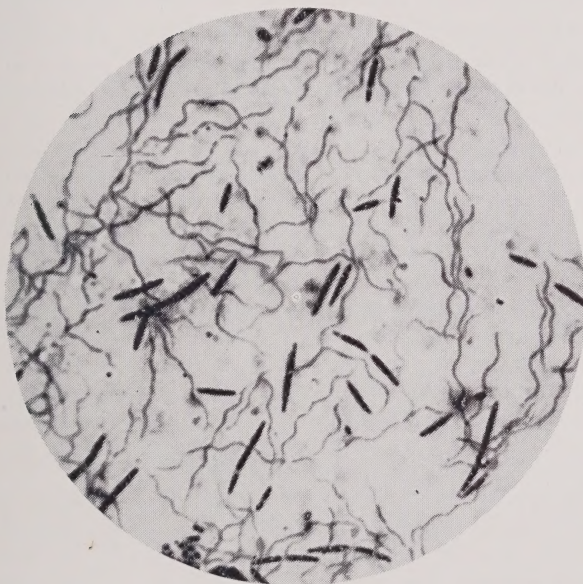


FIG. 1 — Oil-immersion photomicrograph of a smear taken from a case of necrotic gingivitis. The fusiform bacillus and the spirillum are both present.

Introduction

Necrotic gingivitis is a member of that group of diseases that is made more important by war. The last war was responsible for one of its many names—"trench mouth". The present war has brought the disease into prominence again and so disclosed that many aspects of it are still not understood.

Etiology

It is almost fifty years since Plaut (1894) and later, Vincent (1896) established that those lesions of the mouth and throat which are characterized by ulceration, necrosis and gangrene are associated with the presence of a fusiform bacillus and a spirillum. In the gingival form of this disease, which we term necrotic gingivitis, a positive smear for these two organisms is always to be obtained (Fig. 1). But even though almost fifty years have passed since the association between these organisms and the disease became known, the exact role of these two organisms in causing the disease is still relatively obscure. For example, it seems certain that these two organisms can lurk in the mouth, in chronically inflamed gingival tissue, without causing the characteristic clinical picture of necrotic gingivitis (Kirkpatrick, '36). It has been suggested that other organisms which act symbiotically with these must be present if the disease is to be produced (Smith, '30). A virus factor in the production of the disease has received some consideration (Lancet editorial, '42). And although there is abundant evidence to indicate that the disease has often spread throughout closely associated groups of people, there are many instances on record where purposeful attempts to transmit the disease from infected mouths to healthy mouths have failed.

The foregoing tends to suggest that whatever organisms are concerned in the disease may vary in virulence. There is also evidence suggesting that the resistance of the gingival tissues also varies considerably and thus plays an important part in whether or not the disease develops. The tendency of chronically inflamed gingival tissue to harbour the fusiform bacillus and the spirillum has already been commented on and it is almost axiomatic that, to eradicate the disease, sites of chronically inflamed gingival tissue must be eliminated. But the resistance of the gingival tissues depends on more than local factors which dispose to chronic inflammation, indeed the resistance of the gingival tissues bears a profound relationship to certain aspects of nutrition. Lind's accounts of outbreaks of scurvy amongst sailors on long voyages of a hundred and fifty years ago are illustrative of this point. His descriptions of the mouths of so many of these men suggest very strongly that necrotic gingivitis often became superimposed on the scorbutic state. Recent work (Topping and Fraser, '39; King, '40; Schwartzman and Grossman, '42) all suggest that vitamins of the B complex are also very important factors in maintaining resistance toward necrotic gingivitis, particularly nicotinic acid. But the fact that necrotic lesions tended to appear in the mouths of monkeys kept on the Goldberger diet, as reported by Day, Langston, Darby, Wahlin and Mims ('40), even though this diet was supplemented with ascorbic acid, nicotinic acid, thiamin chloride and riboflavin, suggests that factors other than vitamin C and the B complex are concerned in the resistance of the gingivae. And, as the gingival condition of these monkeys was associated with a leucopenia, and as necrotic lesions of the gingivae tend to develop in agranulocytic angina in man, it might be questioned if the resistance of the gingivae is not normally dependent in part on the constant migration of granular leucocytes through these tissues into the mouth.

It is obvious that all the various factors in, and theories about, the etiology of the disease cannot be evaluated properly at this time. It is one of those occasions when it seems wise to adopt, for the time being, a conservative view. Such a view, in our opinion, would embrace the following propositions:—

1. That the disease is primarily an infection.
2. That the fusiform bacillus and the spirillum are concerned in the infection and hence a positive smear for these organisms may be obtained when the disease is present.
3. That the disease should be regarded as communicable.
4. That a person may harbour the fusiform bacillus and the spirillum in chronically inflamed gingival tissue without having the disease. Hence a positive smear for these organisms does not necessarily indicate that a person has necrotic gingivitis; the smear must be evaluated in relation to the clinical picture and the history of the disease.
5. That whether any given person exposed to the causative organisms, either from his own or someone else's mouth, develops the disease can depend upon the virulence of the organisms and upon the resistance of the gingival tissues. The latter is affected by both general and local factors. Malnutrition, particularly a deficiency of ascorbic or nicotinic acid in the diet, is an example of a general factor predisposing toward the development of the disease. Local factors predisposing toward the disease are sites of chronic inflammation due to overhanging margins of fillings, calculus, etc.

Symptoms and Signs

Necrotic gingivitis is a disease of the gingival tissues which usually exhibits the following characteristics:—

1. A *sudden onset*.
2. *Ulceration*. This is of a special character. The ulcers are fairly sharply demarcated and are covered with a slough which may be grey, greyish-yellow or greyish-green in colour. Contact ulcers may occur in the contiguous mucous membranes of the tongue, lips or cheek.
3. The disease tends to begin in sites where chronically inflamed gingival tissue forms a wall of a pocket or crevice in which anaerobic bacterial growth readily occurs. Examples of such locations are: the gingival flaps on partially or imperfectly erupted third molars; the interproximal papillae of the upper central incisors; and any site of mechanical irritation such as overhanging filling margins and impinging crowns, clasps, and partial dentures.
4. A strong tendency to elect the tips of *interproximal papillae* as preferred sites of involvement in the *spread* of the disease.
5. A distinctive and peculiarly offensive *odour*. In cases where ulceration and necrosis are extensive the breath is putrid.

6. *Sensitivity.* The affected tissues are sensitive to touch and the chewing of hard foods may be painful. Highly flavoured foods often cause considerable distress.

7. Bleeding, increased salivation, and frequently, a metallic taste in the mouth.

8. A *positive* smear for the fusiform bacillus and the spirillum.

9. The patient may feel out-of-sorts and have fever and other general manifestations.

Histopathology

The histopathology of necrotic gingivitis in man has, on the whole, received extraordinarily little study. To our knowledge probably not more than a half dozen pieces of tissue evidencing the disease have been sectioned and examined under the microscope. The chief reason for this lamentable state of affairs is, of course, the difficulty of obtaining tissue.

Necrotic gingivitis is not a fatal disease, hence, with some exceptions, such tissue as is obtained must be procured by biopsy. And such studies as have been made on tissue obtained this way (Box, '24, '30; Cahn, '29; and Fish, '39) have been brief. Only one investigation made on autopsy material has come to our notice, namely that of Gottlieb and Orban ('36). Because of the scarcity of information on the nature of the lesions of necrotic gingivitis, there has been a tendency to use knowledge obtained from histopathological studies of cancrum oris and Vincent's angina (tonsil) to interpret the lesions in necrotic gingivitis, and this may not be entirely justified. In view of this state of affairs, and the present-day renewed interest in the disease, it was thought it would be helpful to review the material obtained by Box some years ago, together with some additional material, and report on the histopathology again in more detail, particularly with regard to its importance in applying a rational therapy to the disease.

Low-power photographs of sections of two lesions are shown in figs. 2 and 3. In both these lesions the striking feature is that necrotic gingivitis offers an example of diphtheritic, or what some pathologists might term, diphtheroid inflammation. These terms are given, not because the lesion is caused by the bacillus that causes diphtheria, but because the histopathological picture is similar to that seen in diphtheria. In diphtheria, it will be recalled, the organisms cause a superficial necrosis of tissue which becomes demarcated from the underlying tissue by a wall of fibrinous exudate. The fibrin which is laid down between the living and the necrotic material, and which often binds the necrotic material together, thus forms a membrane which covers the surface. This is not a true membrane because it is not living tissue. As it consists only of fibrin and necrotic tissue, it is commonly called a pseudo or false membrane.

Where ulceration has occurred, necrotic gingivitis, therefore, offers an example of diphtheritic or diphtheroid inflammation. The lesions demonstrate three zones. The most superficial zone consists of necrotic material and bacteria. The deepest zone consists of living tissue which is the seat of an acute inflammatory process. Between the zone of necrosis and the zone of acutely inflamed living tissue there is a membrane or zone of fibrin.

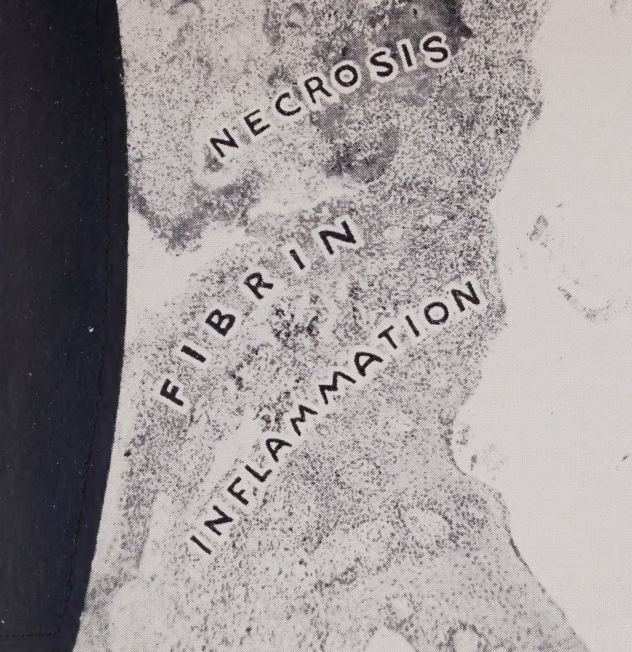
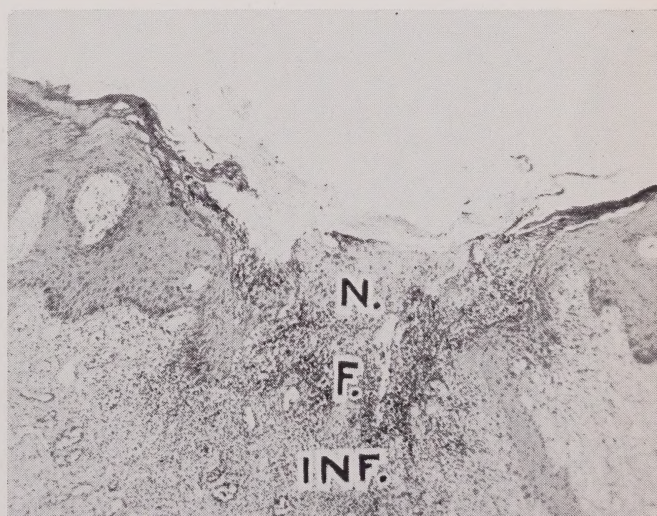


FIG. 2 — Low-power photomicrograph of a piece of gum removed from a case of necrotic gingivitis. Side of a tooth (black) is painted into photograph to show former position of removed and sectioned tissue. Uppermost part of photomicrograph represents the necrotic tip of an interproximal papilla, the lowermost part, relatively healthy gum tissue. The necrotic tissue is so designated in the photograph and is seen to be separated from an underlying zone of inflamed tissue by a zone of fibrin.

In all the sections, these zones were not as clearly delimited as the above description might indicate. But even when the zones were not clearly demarcated in a section, for example when there was a mixture of fibrinous exudate and necrotic material, the tendency of the dead material to be walled off from the living by a zone of fibrinous exudate was always apparent. The three zones will now be considered in more detail.

1. THE ZONE OF NECROSIS. In sections stained with Giemsa's stain, the necrotic material was found to be literally swarming with fusiform bacilli. An oil-immersion photomicrograph of this zone in a Giemsa-stained section is illustrated in fig. 4. The bacilli were so numerous they seemed to comprise the bulk of the material in the necrotic zone. A few examples of the spirillum were also seen in this zone but they were not nearly as numer-

FIG. 3 — Low-power photomicrograph of a section of an ulcer from another case of necrotic gingivitis. The three zones of necrosis, fibrin, and acute inflammation are also to be seen in this section.



ous as the fusiform bacilli. Other forms of bacteria were also seen but the fusiform bacilli were by far the most prevalent organisms.

2. THE ZONE OF FIBRIN. This was of variable width. For the most part the fibrin was not present in the form of threads but instead, in thick bands which form a feltwork (Fig. 6). Such an arrangement of fibrin is commonly termed a hyalin reticulum.

The part of the zone of fibrin which bordered the zone of necrosis was in very close contact with the organisms (Fig. 5). Fusiform bacilli could be seen in close apposition to the fibrin and often the histological picture suggested that the organisms were growing into the fibrin. This picture could, however, be interpreted another way, namely that organisms had grown up to the fibrin wall where they were more or less effectively stopped.

Below the zone of fibrin the inflammation was acute. The capillaries and venules were widely distended (Fig. 8). Close to the zone of fibrin, the blood vessels were often encircled by rings of fibrinous exudate (Fig. 7). Polymorphonuclear leucocytes were numerous in the tissue close to the zone of fibrin.

3. THE ZONE OF ACUTE INFLAMMATION. Beneath the zone of fibrin the tissue presented a picture of acute inflammation. Close to the zone of fibrin the exudate seemed to consist chiefly of fibrin and polymorphonuclears (Fig. 7). In the region a little further removed from the zone of fibrin, fibrinous exudate was not so prominent. Fusiform bacilli were not found in this zone. The tissue here was edematous and infiltrated with polymorphonuclears (Fig. 8). The capillaries and venules were widely dilated. The zone of inflammation merged gradually into underlying healthy tissue.

Differential Diagnosis

From the foregoing it is obvious that necrotic gingivitis is an *acute* condition with a characteristic set of signs and symptoms, and that it depends upon a characteristic pathological lesion in which ulceration, fibrin formation and slough are prominent features. This acute disease with its sudden onset cannot, then, be easily confused with the various types of chronic gingivitis which prompt so many people with inflamed gums to seek the services of a dentist. Yet certain examples of chronic gingivitis may offer some difficulty in the differential diagnosis. For example, in many cases of chronic gingivitis, the smear for the fusiform bacillus and spirillum may be positive. Indeed, it is not certain if there may not be some form of chronic or sub-acute disease in which these organisms play a part. But these cases are not examples of necrotic gingivitis. The picture of an acute disease with ulceration and slough formation is not present. It should be remembered, of course, that it is always possible for one of these cases to become an acute, and so, typical case of necrotic gingivitis, and also that necrotic gingivitis may develop on top of an old chronic gingivitis of any sort.

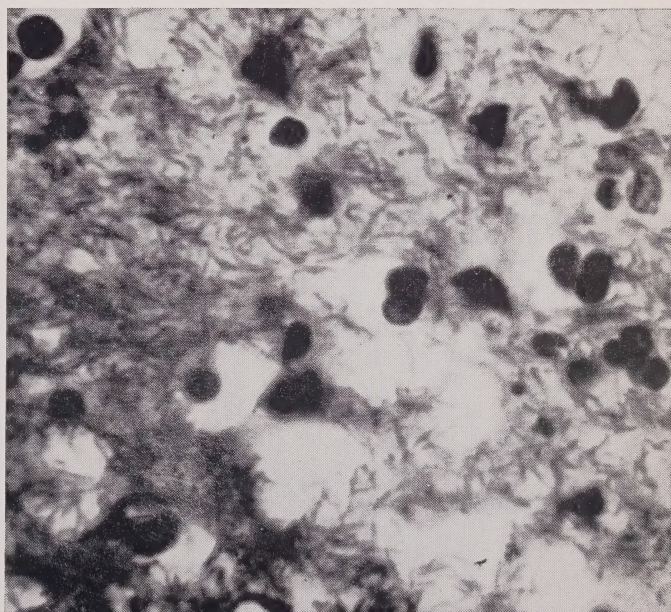
In the experience of one of us (Box), there is another form of gingivitis which is not easily distinguished from necrotic gingivitis. This is not well-known nor has it been investigated thoroughly. It is an acute disease, hence, like necrotic gingivitis, it has a sudden onset. It resembles necrotic gingivitis in still another way; it leads to the development of

ulcers which are sometimes covered with a very adherent exudate. But the disease differs from necrotic gingivitis in certain respects. It does not exhibit predilection for the tips of the interproximal papillae in its spread; it is not associated with the characteristic odour of necrotic gingivitis, and lastly it does not yield a positive smear for the fusiform bacillus and the spirillum. A report of a disease having many points in common with this, and associated with a Gram-positive diplococcus has recently been made by Walton, Graham and Lansdown ('41) in England. It seems not unlikely that many cases of this other form of acute gingivitis have in the past been diagnosed erroneously as necrotic gingivitis.

The Evaluation of the Smear in the Diagnosis of Necrotic Gingivitis

In a sense, a negative smear is more informative than a positive smear. A negative smear rules out necrotic gingivitis but a positive smear does not, in itself, establish that the disease is present. Many sorts of chronically inflamed gingival lesions will yield a positive smear. So a positive smear must be evaluated in conjunction with the clinical findings.

FIG. 4—Oil-immersion photomicrograph of a site in the zone of necrosis; Giemsa stain. It is to be observed that this necrotic material is swarming with bacteria and that the fusiform bacillus is the predominant organism.



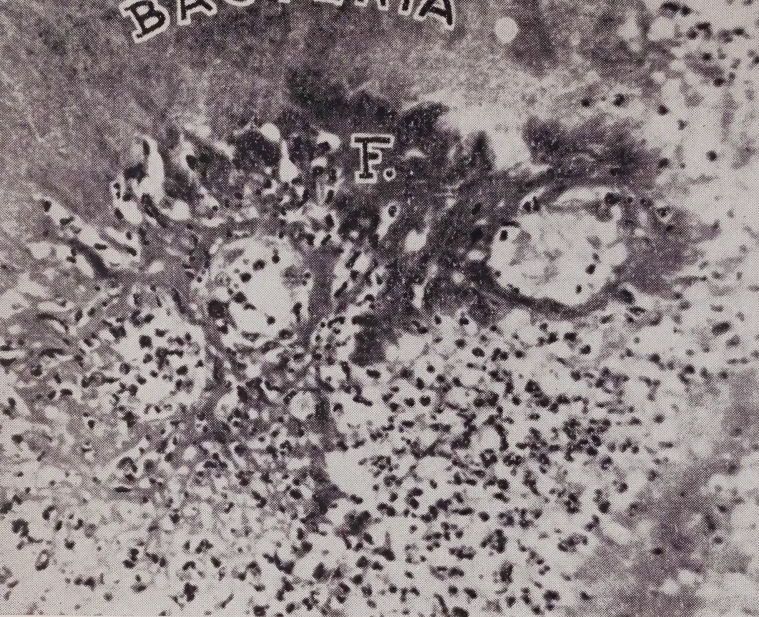


FIG. 5—Medium power photomicrograph of junction between band of fibrin and zone of necrosis. Three blood vessels surrounded by fibrin appear in the middle of the picture. The fibrin extends above them and borders the zone of necrosis. Bacteria in this zone impart a granular appearance to it. This granular appearance is seen extending to the fibrin which is of a darker colour.

Treatment

Many different kinds of treatment, and combinations of different methods have been used in this condition. Mouthwashes of various kinds have been used. Some of these depend for their alleged efficacy upon the presence of oxygen-liberating chemicals such as sodium perborate and hydrogen peroxide. Others contain antiseptics of different sorts. Then, another method of treatment frequently combined with mouthwashes, depends on swabbing or painting the affected tissues with various solutions, for example, Fowler's solution or other arsenicals or substances such as tannic acid and chromic acid. Perhaps the best treatment of this sort is the one devised by Adams of Toronto during the last war and which consists essentially of painting the slough covering the ulcers with Churchill's iodine and a *thirty-five percent* aqueous solution of silver nitrate. This acts by coagulating the slough and forming therein silver iodide, so that the slough becomes an antiseptic dressing which allows epithelization to proceed beneath it. This is still the treatment of choice when ulceration is extensive in the posterior part of the mouth, and when ulcers are present on surfaces in the mouth other than those of the gingival tissue, such as cheeks, lips and floor of the mouth.

The most recent advance in the treatment of necrotic gingivitis depends, however, upon the employment of a radically different technique. In the experience of one of us (Box) it yields such good results that it must be regarded as marking a definite step forward and is now the treatment of choice in the majority of cases. The first application of this new method of treatment was made by Fish ('38). It consisted essentially of applying a dressing or packing to the gingival tissues. Fish used a dressing of zinc

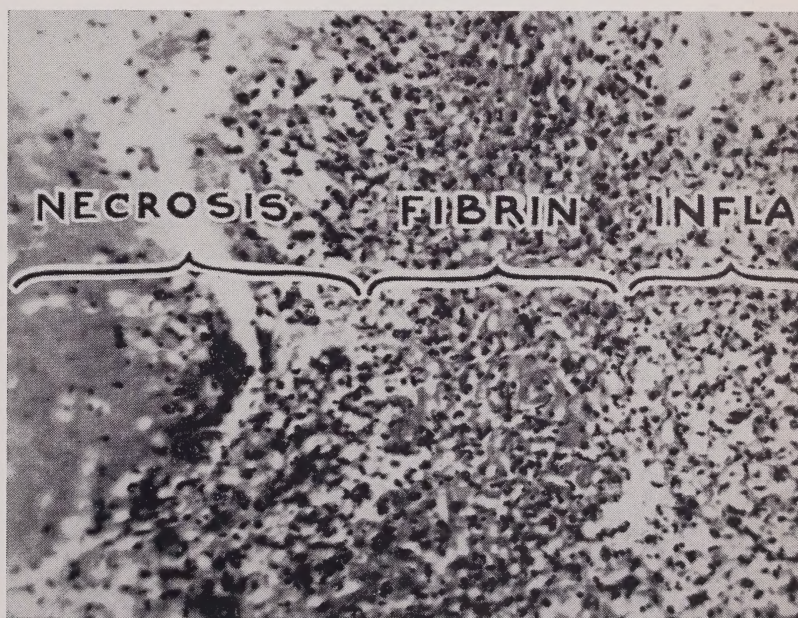
oxide, and eugenol or oil of cloves. According to his method, wisps of cotton saturated with this material are gently packed into the gingival crevices and interproximal spaces. Enough additional wisps are gently applied so that when the mixture sets, the effect of a light splint is obtained.

The first experience of one of us (Box) with a dressing that sets, in the treatment of gingivitis, dates back about three years. It was first tried in the treatment of chronic gingivitis and its employment here evolved from using a special surgical dressing* in cases of gingivectomy. The dressing employed was the excellent one developed about eight years ago by Kaiser of Los Angeles, California, and Kirkland of Montgomery, Alabama. During its use following gingivectomy, wider applications of treatment in the mouth were tried, and it was found to produce very beneficial effects on chronically inflamed gingival tissues. Later, the almond oil was omitted, and the dressing, so modified, was used as a routine procedure in cases of chronic gingivitis, and in the preparation of the soft tissues for tooth removal. The dressing was further modified for use in cases presenting subacute symptoms, and in cases of necrotic gingivitis. This was accomplished through the addition of kaolin (B.P. and sterilized) which, aside from increasing its adsorbent properties, made for greater ease of application in the mouth.

* The formula for this dressing was received by personal letter from Dr. Kirkland. The dressing is made by mixing a powder and a liquid. To make the powder, the ingredients are measured by volume. Equal parts of zinc oxide and powdered rosin are mixed, and to four parts of this mixture, one part of tannic acid (flakes) is added. The whole is now thoroughly stirred and mixed. The liquid comprises one part of bitter almond oil and two parts eugenol. Before mixing these liquid constituents, the eugenol is poured into a test tube and a lump of rosin is added. This is warmed over a bunsen flame and when the rosin is melted, the almond oil is added. The powder and liquid are mixed on a cement slab to a thick and heavy consistency. In the final phase of mixing, more powder is incorporated with the fingers until a stiff mass is produced.

It may be noted that Merritt has recommended sweet instead of bitter almond oil in the making of the liquid. (Periodontal Diseases, Second Edition, 1939.)

FIG. 6—Medium-power photomicrograph to show all three zones. The fibrin, in the form of a hyalin reticulum, can be seen passing down the middle of the photomicrograph separating the zone of necrosis on the left from the zone of acute inflammation on the right.



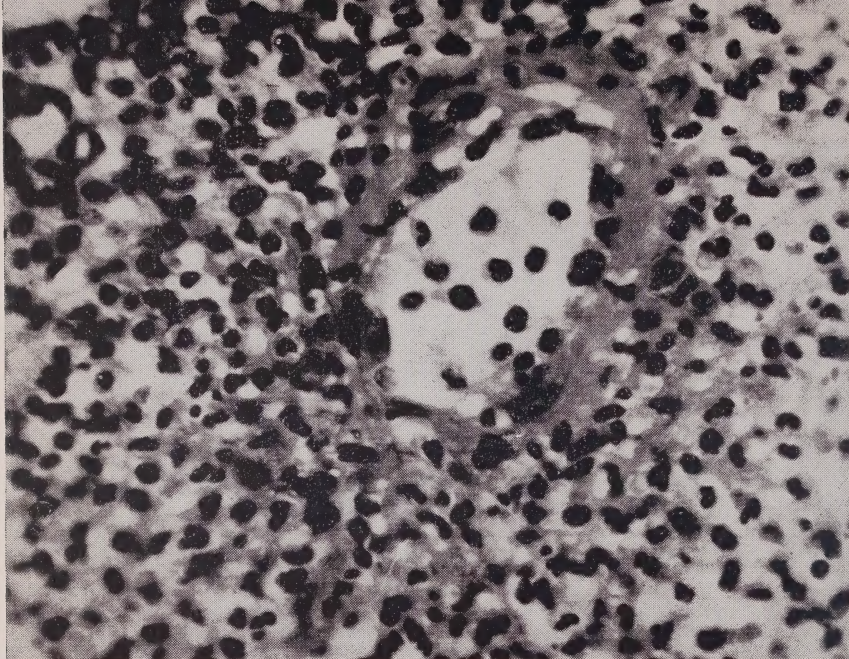


FIG. 7—High-power photomicrograph of the zone of inflammation close to the fibrin. The blood vessel seen in the centre is surrounded by fibrin and a great many polymorphonuclear leucocytes can be seen in the exudate surrounding the vessel.

This addition necessitated a slight change in the amounts of rosin and tannic acid. Somewhat later, thymol was added to the eugenol chiefly because of its antiseptic and fungicidal properties.

The dressing now advocated for necrotic gingivitis and which has been found to be the most effective of various modifications of the Kaiser-Kirkland surgical dressing tried, consists of two parts, a powder and a liquid*. These must be thoroughly mixed.

The Powder

Zinc oxide	40 parts
Powdered Colophony (Rosin)	45 "
Tannic acid	10 "
Kaolin (sterilized)	2.5 "

The parts are measured by volume. The powder in sufficient quantity for the day is freshly mixed in the morning. The use of an ordinary set of graded spoons is recommended for measuring the above ingredients by volume.

The Liquid

Thymol	2.0 Grams
Eugenol	98.0 Cubic Centimeters

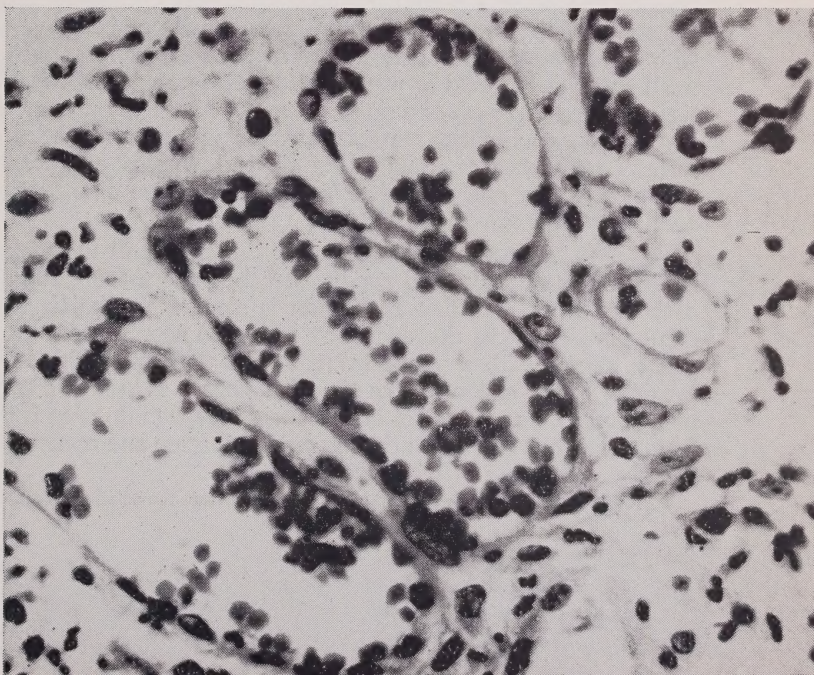
* Zinc oxide is protective and is somewhat antiseptic and astringent. It also has a slight sedative action when applied locally. Rosin is a rubefacient, and its presence in the dressing increases its adhesive properties and hastens the setting time. Tannic acid is astringent and a local hemostatic, and has long been used in dentistry for inflammations of the oral mucous membrane. Eugenol is an antiseptic with a Rideal-Walker phenol-coefficient of 8.6. It also has local anesthetic properties. Thymol is an antiseptic with a Rideal-Walker coefficient of 20.0. It is also well-known for its fungicidal properties.

Steps in the Treatment

1. THE MIXING OF THE DRESSING. This should be done before the subsequent steps of the treatment are undertaken. Six or eight drops of the liquid and a suitable quantity of powder are placed in close proximity on a glass or porcelain slab. Sufficient powder is shifted into the liquid to completely absorb it, and the two are now slowly and thoroughly incorporated. This is accomplished with broad circular strokes of the spatula. For the first dressing, and usually for the second, the mixture should approximate the consistency of soft putty. If the flat side of a dry spatula is pressed into it and lifted, the material adheres to it, and does not break off from the main mass until the spatula has been lifted about an inch. The drawn-out mass, however, tends to remain drawn-out; it does not retract to any great extent. Any surface of the mixture not interfered with tends to have a glossy appearance. As noted above, this mixture is suitable for the first and usually for the second dressing of necrotic gingivitis, and it will hereafter be called the *first mix*.

For subsequent dressings, used after the surface of the lesions have become covered with epithelium, and after the inflammation has subsided, the mixture used should be much stiffer than that used for the first one or two dressings (the first mix). The stiffer mixture, hereafter called the *second mix*, contains relatively more powder, hence it exhibits a dull,

FIG. 8—High-power photomicrograph of the zone of inflammation further removed from the zone of fibrin. Widely-dilated venules and capillaries may be seen together with polymorphonuclears which are migrating into the tissue.



rather than a glossy, surface (Fig. 9). If a spatula is pressed into this mixture and lifted, the material, while somewhat tacky, does not follow it to any extent.

2. REMOVAL OF SLOUGH. When a considerable amount of necrotic material is present on the surface of the lesions, it should be removed before the dressing is applied. The slough can be removed in different ways, but the gentlest and most efficacious method, in our opinion, is to dissolve it with suitable enzymes. A freshly-made semi-fluid paste of caroid powder and water is a very satisfactory agent for this purpose. This is easily made by mixing about a half-teaspoonful of the powder with enough water to make a paste of a creamy consistency. With a small spatula this is carried and gently applied to the lesions. It does no harm if the paste runs along gingival borders and into crevices. This paste is allowed to remain in place for about two minutes with the lips closed. The mouth is then rinsed with a half-glass of tepid water. The surface of the lesions will now be found to be almost completely free of slough.

3. PREPARATION OF THE TOOTH SURFACES. Although the interproximal spaces are used as extensively as possible to retain the dressing, the gentleness which the treatment of necrotic gingivitis demands does not allow these spaces to be used as effectively as they may be in less acute conditions. Hence this method must be supplemented by another, namely that of applying the dressing to tooth surfaces in areas under treatment in such a way that the dressing adheres firmly to the tooth surface and extends over the gingival tissue under treatment. As this method of attachment of the dressing depends upon the dressing becoming cemented to the tooth, it is obvious that the tooth surface must first be thoroughly cleansed of all fatty material. Carbon tetrachloride is the best cleaning agent for this purpose.

The dressing should not be applied to various teeth haphazardly. It is best to deal with one group of teeth at a time. A convenient method is to divide the upper and lower teeth into three groups each; right, left, and anterior. In dealing with the upper teeth, each group to be treated is protected by the insertion of cotton rolls labially or buccally. In dealing with the lower teeth, cotton rolls are placed lingually as well. With a small cotton pellet held in pliers and dipped into carbon tetrachloride, the surfaces of several teeth of a single group are thoroughly cleaned. Frequently two or three applications are necessary. Using a circular motion, the tooth surfaces are rubbed carefully to the gingival margins, and dried with the end of a cotton roll. Dressing is applied to these cleaned teeth before additional teeth are prepared.

4. APPLICATION OF THE DRESSING. When a small ulcer is present on the tip of an interproximal papilla, and tends to be localized on its labial or buccal aspect, the first application is made from the *lingual* side. A small portion of the dressing (first mix), a quantity about the size of a pea, is carried with a plastic instrument to the lingual side of the interproximal space, and with the tip of a finger* is gently pressed into it until it appears on the labial or buccal side. Enough dressing is then added from the lingual side to fill the interproximal space and cover the tip of the

* Coating the finger-tip with kaolin will serve to prevent the adhesion of the dressing to it.

papilla. Next the labial or buccal aspect of the papilla is dealt with. A small portion of the dressing is carried to the interproximal tooth surfaces near the ulcer and is pressed gently inwards and towards the gingival tissues. It thus comes in contact with the first packing and enough is applied so that it flows over any part of the ulcerated surface yet uncovered. The material should be allowed to flow into the gingival crevices as well; in fact, it should be encouraged to do so. When the ulcer is completely covered and the interproximal space filled, the whole mass of packing is gently pressed and manipulated from both sides at once so that, when it sets, it will be well-locked between the teeth.

When the ulceration tends to be localized on the lingual aspect of an interproximal papilla, the procedures that are employed are the same as the above but they are employed in the reverse order. The first application is made from the *labial* or *buccal* side and the last from the lingual side.

When the tip of a papilla is entirely destroyed, the ulcer is covered with the dressing (first mix) by placing two portions of it on the interproximal tooth surfaces near the ulcer, one on the labial or buccal side, and the other on the lingual. Following their adhesion to the teeth, these portions are gently pressed inwards and towards the soft tissues until they unite and cover the ulcer. The interproximal spaces are filled as before.

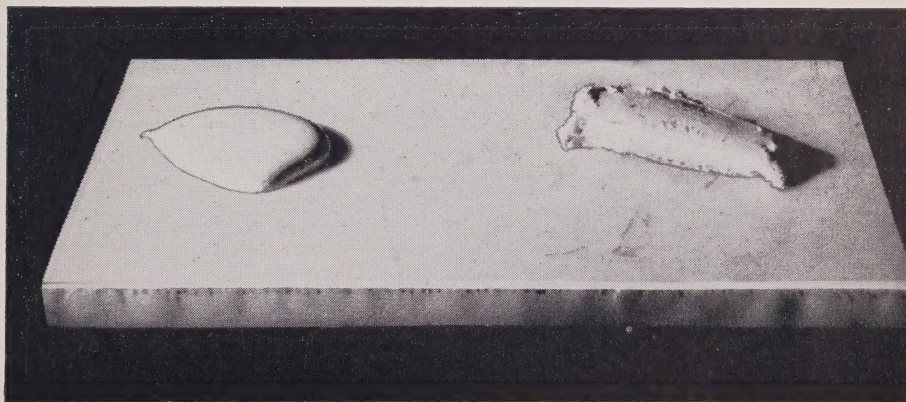
Where the gingival margins, other than those of the papillae, are ulcerated, small portions of the dressing (first mix) are carried to adjacent tooth surfaces. Following satisfactory adhesion to these surfaces, the dressing is firmly pressed along the tooth and is made to flow gently over the soft tissue surfaces. After the ulcers are covered, more material is added so that these packings become joined to those of the interproximal spaces. In badly affected regions, therefore, the dressing over the involved teeth is continuous.

In all steps of the treatment it is of the greatest importance that all manipulation of the affected tissues should be as gentle as possible. Neglecting to observe suitable precautions in this respect may lead to bleeding and this interferes with the adhesion of the dressing. Furthermore *the application of pressure to tissues inflamed as acutely as they are in necrotic gingivitis is to be avoided at all costs.*

In all cases it is advisable in the first treatment to coat the surface of the dressing, together with the bordering surfaces of the teeth and soft tissues, with copal varnish (25 percent gum copal in alcohol). This is

FIG. 9

The two mixtures of the dressing are shown on a porcelain slab. The one on the left is the "first mix"; on the right is the "second mix".



applied with a small pledget of cotton. It is usually noted that some of the mixture of varnish and dressing flows into all the neighbouring gingival crevices. The varnish is precipitated on the application of water following a few seconds interval.

Prior to the necrosis of the tips of the papillae, these tissues become swollen; their surfaces lose their normal stippling and present a smooth and glossy appearance. The colour in most cases is a deep red, changing in some instances to a leaden-grey shade just before the characteristic lesion is established. It should be emphasized that all areas showing these changes should be thoroughly packed with the dressing. When this is done, necrosis of these tissues is prevented, and in this way, the spread of the disease is stopped.

Clinical experience has shown that it is a good policy at the first sitting to apply the dressing to all sites of chronic inflammation in the mouth as well as to the lesions of necrotic gingivitis. In the majority of cases, all that is required, in addition, to produce good results, is the supplemental packing of remaining untreated interproximal regions. In fact, this should be done in all cases despite the absence of chronic inflammation, and with a little practice the procedure can be carried out in a short time.

If ulceration and necrosis are extensive in and about a gingival flap in association with a partially or imperfectly erupted third molar, the Adam's treatment* is employed for this region. But if the lesion in this region is not extensive, the area is treated with the dressing (first mix) instead. This is done as follows. The occlusal surface of the partly erupted tooth is cleaned with carbon tetrachloride and dried. A small amount of the dressing (first mix) is then placed on it and gently squeezed from there under the gingival flap. Enough is allowed to run under the flap to fill the space as completely as possible. The region is then coated with copal varnish.

5. FURTHER CASE MANAGEMENT. All the dressings should be replaced in about two days time. When these are removed it will usually be found that the condition of the gingival tissues is greatly improved. The inflammation will be found to be subsiding and the progress of the disease will be found to have been arrested as witnessed by the fact that interproximal papillae which, without treatment would have become necrotic, are not. The smaller ulcers will already have become covered with epithelium and in the larger ulcers epithelization will be progressing from their margins while their central regions will have become covered with healthy-looking granulation tissue. All the gingival tissues will appear a lighter colour than formerly and the patient will report that he has been greatly relieved of pain and discomfort.

The second application of the dressing is performed in the same way as

* As previously indicated, this is the treatment of choice for extensive lesions in the third molar region. This also applies to lesions on the oral mucosa, e.g., the cheeks, lips, tongue or floor of the mouth. The solutions used are Churchill's Tincture of Iodine and 35% aqueous solution of Silver Nitrate. Pellets of cotton, no larger than a matchhead in size, saturated with these solutions are first prepared. Next, the tissues are gently but thoroughly dried, and the iodine solution applied. This is accomplished by a slight compression of the saturated pellet, the solution flowing over the ulcerated tissue, and into the crevice, in the case of the third molar sites. The application of the silver nitrate follows immediately. This solution combines with the iodine tincture to form silver iodide within the necrotic tissue. A whitish film is formed which later turns dark, and is cast off in about thirty-six hours. Directly following the treatment, the mouth is rinsed with three or four glasses of warm water. Two or three treatments may be required in some cases.

the first one with the exception that the copal varnishing is usually omitted. If the case is a mild one, and the repair of the lesions is well advanced, the second mix may be used at this time. Usually, however, the second dressing is made with the first mix. The second dressing is removed two or three days later and at this time a marked further improvement should be observed. Superficial scaling is now undertaken if required. The removal of the supragingival deposits of calculus should, however, be carried out with a minimum of gingival trauma. Using special rubber cups, the crowns of the teeth are polished. Brush wheels should not be employed for this purpose. After the teeth are cleaned and polished, a third application of dressing is applied and this time the second mix is used. This may be left on for three or four days before it is removed. From this point on, the treatment should be conducted along the regular lines of periodontal case-management. This usually involves further scaling and the elimination of all manifest causes of gingival irritation such as overhanging margins of fillings and impinging dental restorations. Faulty contact points of teeth should be restored to prevent further food impaction. Throughout these procedures, further packings may be indicated.

Traumatogenic occlusion should be eliminated as far as possible. From clinical observation, it is clear that this factor has a bearing on the resistance of the gingival tissues. In some cases, the majority of the lesions of necrotic gingivitis, apart from those in the third molar region, are localized in situations where a definite traumatogenic occlusion can be demonstrated. This is commonly exhibited in cases of recurrent necrotic gingivitis, (see MacKay '37). The most ideal conditions of occlusal function should therefore be established.

The case-management of necrotic gingivitis should not be considered complete without the elimination of all major zones that may afford favourable cultural conditions for fuso-spirochetal organisms. Chief of these is the third molar region. In many cases, eradication of the associated pocket is best accomplished through the removal of the tooth. In some instances, excision of the overlying tissues is all that is required to permit the establishment of hygienic conditions. In both instances, these operations should be carried out after all the gingival tissues have been restored to a state of health. In no case should any surgical procedure be undertaken while necrotic lesions are present in the mouth.

The Problem of Recurrent Infection

Cases of recurrent infection have been the concern of many dental practitioners. When lesions of necrotic gingivitis return from time to time following treatment, it is often the case that the disease was not eradicated in the first instance. Frequently, there has been failure to carry out the after-phases of treatment. True re-infection may of course take place, and as Wilkin, ('41), has pointed out, in these cases the sources of infection must be brought under control in the patient's environment. However, the possibility of re-infection is greatly decreased when the tissues are restored to a high state of resistance.

Summary

1. Various factors relating to the cause of necrotic gingivitis are discussed. The importance of the various bacterial and nutritional factors related to the development of the disease is not, as yet, entirely clear. What is described as a conservative view regarding the disease is presented.

2. The signs and symptoms of the disease are described and its differential diagnosis is discussed.

3. Histopathological studies made on pieces of gingival tissue removed at biopsy from two cases are reported on. Essentially, the lesion is of a diphtheroid type, and reveals a superficial zone of necrosis which swarms with bacteria and which is separated by a zone or membrane of fibrin from the underlying tissue which is acutely inflamed.

4. Various methods of treatment are commented on and a method of treating the condition by the application of an adherent dressing composed of zinc oxide, rosin, tannic acid, kaolin, eugenol and thymol is described. The various steps taken in the application of this dressing are explained in simple terms. It is pointed out that the dressing not only exerts a curative action on frank lesions in the mouth but, in addition, possesses the great virtue of being a suitable coating for tissue which is not yet seriously affected and so serves to prevent the spread of the disease.

I wish to make grateful acknowledgment to Doctors C. E. Sutton and G. H. Coram for assistance in the clinical testing of the dressing in its various modifications; and to Mr. A. A. Norton, of the J. F. Hartz Co. Ltd., for valuable suggestions regarding the materials employed.—H.K.B.

References

- BOX, 1924. Studies in periodontal pathology. Bull. no. 7, Can. Dental Res. Found.
BOX, 1930. Necrotic gingivitis. Bull. no. 14, Can. Dent. Res. Found.
CAHN, 1929. The penetration of the tissue by Vincent's organisms. Journal of Dental Research, IX, 695-698.
DAY, LANGSTON, DARBY, WAHLIN, and MIMS, 1940. Nutritional cytopenia in monkeys receiving the Goldberger diet. Journal of Experimental Medicine, 72, 463-477.
FISH, 1938. Acute ulcerative stomatitis. Lancet, 2, 558-560.
FISH, 1939. Acute marginal gingivitis. British Dental Journal, 66, 468-469.
GOTTLIEB and ORBAN, 1936. Zahnfleisch-Entzündung und Zahnlockerung. Berlinische Verlagsanstalt.
KING, 1940. Vincent's disease treated with nicotinic acid. Lancet, 239, 32-35.
KIRKPATRICK, 1936. Bacteriology of periodontitis. Dental Journal of Australia, 8, 607-615.
Lancet Editorial, 1942. Virus or Vitamin? Lancet, 242, 233.
MACKEY, 1937. A stubborn case of Vincent's infection. The Journal of Periodontology, 8, 53.
PLAUT, 1894. Deut. med. Woch., xlix.
SCHWARTZMAN and GROSSMAN, 1942. Vincent's ulceromembranous gingivostomatitis. Archives of Pediatrics, 58, 515-520.
SMITH, 1930. Fusio-spirochetal disease of lungs produced with cultures from Vincent's Angina. Journal of Infectious Diseases, 46, 303.
TOPPING and FRASER, 1939. Mouth lesions associated with dietary deficiencies in monkeys. U.S. Public Health Report, 54, 416-431.
VINCENT, 1896. Ann. de L'inst. Pasteur, Bull. et mem. de la soc. med. des hop. de P.
WALTON, GRAHAM and LANSDOWN, 1941. Acute ulcerative stomatitis, three unusual cases. Lancet, 2, 214-216.
WILKIN, 1941. An effective sequence in the treatment of Vincent's Angina. New Zealand Dental Journal, 37, 73-74.

The Canadian Dental Research Foundation

is the official Research Organization of the Dental Profession in the Dominion of Canada, two Directors being appointed by the Dental Board of each Province, and two Directors appointed, ex-officio, by virtue of their office in the Canadian Dental Association.

All subscriptions are forwarded by the Secretary to the National Trust Company, Trustees, the interest only being used in support of research work in the several Dental Colleges of Canada.

This Bulletin is the Twenty-fifth of a series of Bulletins to be issued by the Foundation. Complimentary copies of all Bulletins issued will be sent to Canadian Dental Practitioners.

Any Dentist in Canada who feels that he has any original work worthy of publication is requested to forward it to the Foundation.

Copies of this Bulletin may be obtained from the Secretary, Canadian Dental Research Foundation, Room 312, Medical Arts Bldg., 170 St. George St., Toronto, Canada.

Bulletins Published by the Foundation

- No. 1.—The Evolution of the Periodontal Pus-Pocket, May, 1921, H. K. Box. (31 pages, 27 Illustrations.)
- No. 2.—The Rupert Hall Method for Entire Upper and Lower Dentures, July, 1921, W. E. Cummer. (50 Pages, 38 Illustrations.)
- Nos. 3 and 4.—The Dentinal-Cemental Junction; Histological and Histo-Pathological Studies of the Dental Pulp, May, 1922, H. K. Box. (60 Pages, 82 Illustrations.)
- No. 5.—The Science and Practice of Partial Denture Service, with Special Reference to a Graphic Method of Design, May, 1922, W. E. Cummer. (27 Pages, 16 Illustrations.)
- No. 6.—Combinations as an Aid in the Discovery of Fundamentals in Dentistry, and Other Sciences, May, 1923, W. E. Cummer, G. R. Anderson, Robert J. Reade. (71 Pages, 120 Illustrations.)
- No. 7.—Studies in Periodontal Pathology; The Mechanics of Occlusion, Summary of the Signs of Incipient Periodontal Disease (issued in conjunction with the Department of Health, Province of Ontario), May, 1924, H. K. Box, G. R. Anderson. (120 Pages, 135 Illustrations.)
- No. 8.—Articulation for Partial Dentures with the Snow Apparatus and Wadsworth Incisor Guide, June, 1924, W. E. Cummer, I. H. Ante, J. A. Bothwell. (45 Pages, 39 Illustrations.)
- No. 9.—Combinations which Occur Between the Upper and Lower Six Posterior Natural Teeth in Occlusion, June, 1924, W. E. Cummer, G. R. Anderson, R. J. Reade. (18 Pages, 13 Illustrations, including folded Chart.)
- No. 10.—Treatment of the Periodontal Pocket (issued in conjunction with the Faculty of Dentistry, University of Toronto, September, 1928, H. K. Box. (124 Pages, 120 Illustrations.)
- No. 11.—Impressions in Partial Denture Service (presented at the Ontario and Canadian Dental Associations, 1926, and reprinted, with additions, from "Dental Cosmos", September, 1926; December, 1927; January, 1928; March, 1928; and January, 1929), October, 1929, W. E. Cummer, R. J. Reade. (70 Pages, 76 Illustrations.)
- No. 12.—Special Cavity Preparations and Castings Processes for Gold Inlays, Including Some of the Physical Phenomena Taking Place in the Materials Used, and Methods of Compensating for the Shrinkage of Gold, January, 1929, H. E. Bulyea.
- No. 13.—Ultra-Violet Rays, Their Application in the Practice of Dentistry, 1929, Robert J. Reade.
- No. 14.—Necrotic Gingivitis (Trench Mouth), 1930, Harold Keith Box.
- No. 15.—Trismus Due to the Involvement of the Mandibular Nerve, 1933, S. W. Leslie.
- No. 16.—A Process for Production of Copper Amalgam from Ingredients in Aqueous Solution, 1933, F. C. Husband.
- No. 17.—The Problem of Fac-simile Reproduction of Anterior Esthetics in Full Denture Prosthesis, 1933, Frank M. Lott.
- No. 18.—Periapical Tissue Changes in Teeth of Dogs, Following Various Methods of Pulp Removal and the Use of Various Common Drugs, 1933, G. A. Buchanan.
- No. 19.—Dental Amalgams, 1935, Thomas Cowling, M.A., D.D.S., B.Paed.
- No. 20.—Red Bone-Marrow in Human Jaws, 1933, Harold Keith Box.
- No. 21.—Bone Resorption in Red Marrow Hyperplasia in Human Jaws, 1936, Harold Keith Box.
- No. 22.—A Theory of a Mechanism Concerned in Tooth Extrusion, 1936, A. F. Fenton and D. P. Sutton.
- No. 23.—Glass as a Denture Base, 1936, Frank M. Lott.
- No. 24.—A Liquefying Amylase in Human Saliva, Amylopectin, and Dental Caries, 1938, Harold Keith Box, D.D.S., Ph.D., F.R.M.S.
- No. 25.—Necrotic Gingivitis, January, 1943, Harold Keith Box, D.D.S., Ph.D., and Arthur W. Ham, M.B.

7 DAYS

THIS BOOK MAY BE KEPT FOR
7 DAYS ONLY
IT CANNOT BE RENEWED

270A-3-71

RK Canadian Dental Research
 1 Foundation
 C38 Bulletin
 no.15-25

Den	415027 oundation Bulletin: # 15-25	NAME OF BORROWER	from to	White	H. Clark	James	Clark	
-----	---	------------------	----------------	--------------	-----------------	--------------	--------------	--

